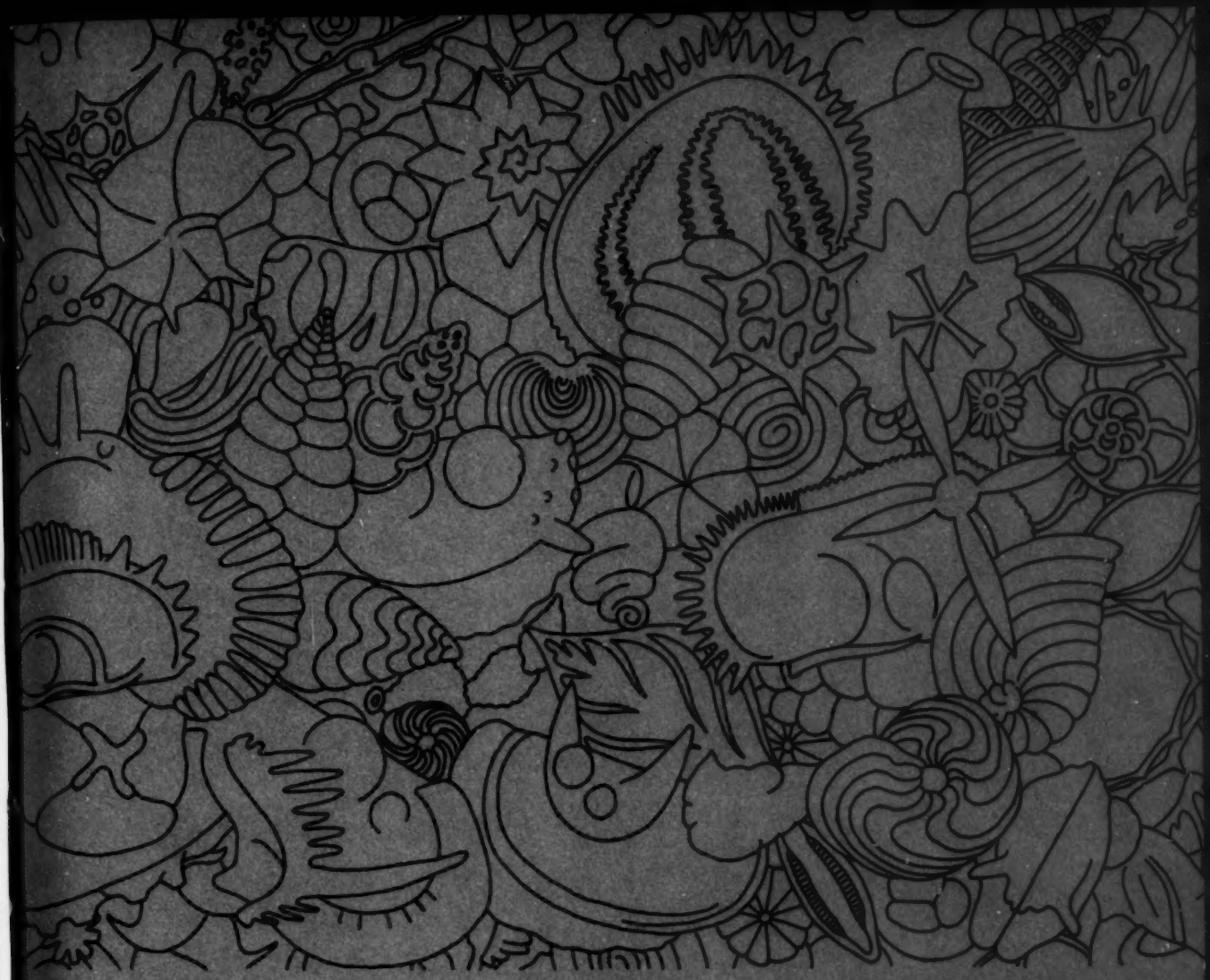

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ABSTRACT: *The problems attendant upon a revision of the Upper Palaeozoic textulariid foraminifera are outlined, and new methods of approach are suggested. The morphology of the group is described in a detailed review of each biocharacter, and the several bioseries are contrasted with the known ontogenic patterns of the genera. The systematic revision recognises the new family Palaeotextulariidae, which includes* Palaeotextularia, Cribrostomum, Climacammina, Cribrogenerina, Deckerellina, Deckerella, Palaeobigenerina, *and* Monogenerina; *assesses the status of* Textularia *and* Bigenerina, *of the family Textulariidae, as Upper Palaeozoic genera; and contains descriptions of several new British palaeotextulariid species. Finally, the stratigraphic distribution and the phylogeny of the forms are reviewed.*

Revision of the Upper Palaeozoic textulariid foraminifera

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EDITORS' NOTE: *This is the second in the series of papers by Dr. Cummings on Upper Paleozoic smaller foraminifera. His first paper, on* Nodosinella, *appeared in Micropaleontology, volume 1, number 3, July, 1955.*

INTRODUCTION

Although Brady (1876) collated most of the earlier records of textulariid foraminifera in the Upper Palaeozoic of Europe and America, and introduced several new forms, his treatment did not reveal their natural unity. (In the present paper, the term "textulariid" is used both in the general sense and for those forms included hereunder in the Textulariidae.) In keeping with contemporary practice, Brady grouped widely divergent forms under one morphologic species, some being referred to extant species, and the close similarity between *Textularia* and the new genus *Climacammina* was ignored by Brady, who placed the latter form within the Trochamminidae.

In 1879, Möller presented a much more detailed account of the textulariid foraminifera of the Russian Carboniferous, and this must be regarded as the first attempt to consider the group as such. Aware of the taxonomic difficulties that arise from the close similarity of ontogenic and morphogenetic patterns within the textulariids, he sought to distinguish juvenile and adult forms on the basis of internal morphology, using such techniques as the mathematical analysis of septal arrangement. Thus, *Textularia* and *Climacammina* were regarded as ontogenic stages of the new genus *Cribrostomum*, and all Palaeozoic textulariids were to be included in this genus. Such treatment proved inadequate. It lacked the support of population analyses at successive stratigraphic horizons, and the details of relative frequencies. Furthermore, Möller failed to appreciate the variations of internal morphology that are produced by fossilisation, or secondary alteration.

With the additional information of succeeding years, Schubert (1907) presented a classification of the Upper Palaeozoic textulariids that is the foundation of all later work. Based primarily on their morphogeny in relation to stratigraphic occurrence, this scheme was adopted by Cushman (1928*a*, 1948), with modifications and additions, in his general classification of the order.

Cushman regarded the test wall of the Upper Palaeozoic textulariids as an agglutinate structure composed of adventitious material bound by a cement, the latter usually calcareous, and considered that the representative genera formed a natural unit, together with the more recent *Textularia*, within the Textulariidae. This concept of the agglutinate nature of the test wall was advocated by Brady and has persisted, being continued in modern practice by such workers as Reitlinger (1950).

Not all workers have accepted the concept, however. Schubert (1920), in distinguishing *Palaeotextularia*, described fundamental differences of structure between it and *Textularia*. Galloway (1933) noted major differences in wall structure between textulariids of the Palaeozoic and later forms. He recognised the former as a distinct group on the basis of differing ancestry. In his opinion, however, further information as to antecedents was necessary before the distinction, and the suggested classificatory subdivision, could be validated. Nevertheless, several later workers have employed such a system of classification, notably Lipina (1948) and Morozova (1949). Although Glaessner (1945) grouped all the Upper Palaeozoic textulariids within the Textulariidae, he noted the distinctive morphologic features of these forms, particularly in the case of wall structure.

The foregoing review indicates two of the three major problems attendant upon a revision of this group of foraminifera. The first of these concerns the systematic position and classification of the group. The complete or partial inclusion of the Upper Palaeozoic textulariids within the Textulariidae must be assessed by detailed morphologic analysis and an estimation of the fundamental importance of the various biocharacters. The widely divergent views of Cushman and Galloway illustrate the importance of the question as to whether or not these forms are to be regarded as a distinct group.

The second basic problem was that touched upon by Möller (1879) and noted by later workers. It would seem that the ontogeny of many representatives of the group reveals, in large measure, the probable phylogeny. Thus, *Palaeotextularia* appears to give rise to *Cribrostomum*, and this in turn to *Climacammina*. Since all stages of growth may be retained within the structure of the test, an individual biserial specimen, when considered out of context, may be an ephebic form of *Palaeotextularia*, or a neanic form of *Cribrostomum*, or a nepionic form of *Climacammina*. The solution to this problem must be sought through detailed morphologic analysis and the recognition of the changing dominance of bioseries within the plexus, through population analyses at successive stratigraphic horizons, and through the recognition of dimorphism. The latter may seldom prove possible, but the effect of dimorphism should not be underestimated. The microspheric generation of a species of *Cribrogenerina* may be very similar to species of *Climacammina*, whilst the corresponding megalospheric generation is distinct.

In addition to the two problems outlined above, a further considerable difficulty lies in the fact that many species have been described on the basis of one or more thin sections in limestone. Often these are demonstrable as random sections, not cut in the axial plane along the length of the test, and hence an accurate determination of their systematic position may be impossible. Thus, a section of a *Climacammina* parallel to the axial plane, but laterally placed, might be misinterpreted as a *Cribrogenerina*. Distortion of specimens, both during and after fossilisation, often adds to the difficulties of interpretation. The solution of this problem lies in the development of a technique that provides a reconstruction of the "solid" form of a specimen from its random thin section in limestone.

By a detailed review of the morphology, a revision of the classification, and an analysis of the ontogeny and phylogeny, this work presents both new and modified methods of approach to the solution of these three fundamental problems. Its treatment of the palaeontology of this extremely important group of foraminifera is largely confined to a consideration at generic level.

The author would like to acknowledge the encouragement and advice he has received throughout this work from Professor T. Neville George and Professor Alan Wood; the assistance in the preparation of the manuscript and figures given by Dr. D. A. Bassett and Mr. G. Larminie of the University of Glasgow, Mr. D. Chandra of the University of London, and Mr. N. Rast of the University of Wales; the generous help of many American experts, including Dr. Helen Tappan Loeblich, Dr. Alfred R. Loeblich, Jr., and Dr. Brooks F. Ellis; and the facilities and collections provided by the Director and officers of H.M. Geological Survey of Great Britain.

MORPHOLOGY

The individual specimen may be considered as a summation of biocharacters, each of which exhibits a certain condition. In the case of the textulariid foraminifera, the essential biocharacters include the test wall, chambers, aperture, septa, and exterior and interior surfaces. The condition of the biocharacter is not necessarily a direct and complete expression of the potentialities for the biocharacter present in the genetic constitution of the stock. Normally it represents a partial expression of these potentialities within the limits imposed by environmental conditions on the one hand, and by the endoadaptative demands of associated biocharacters on the other.

It follows that the changing conditions seen in the bioseries of a particular character need not indicate a trend in the fundamental evolution of the stock.

Progressive modification of the biome may lead to a gradual alteration of the limitations imposed on the genetic constitution. This results in a change of expression within the range of potentialities of the genetic constitution, which is reflected in the trend of the bioseries. Such trends, therefore, are not to be regarded as wholly indicative of evolutionary development.

Furthermore, one bioseries may show a radical alteration that is produced in response to the endoadaptative demands of another biocharacter. Thus, the assumption of the uniserial mode of growth in textulariids necessitates a major alteration in chamber form and, to a lesser degree, often produces an alteration in the bioseries of apertural form. The intensity of the relationship varies widely between biocharacters. Some appear mutually interdependent, whilst others, such as the test wall of textulariids, run independently for the greater part of their bioseries. Again, the dominance of a biocharacter and its ability to influence the bioseries of others may vary during the evolution of the stock.

Classification demands not only detailed morphologic analysis but also an accurate interpretation of the phylogeny of the group. The latter stems from a review of the ontogeny and morphogeny, which are, in turn, dependent on the recognition of biocharacters and the changing pattern of their conditions seen in bioseries. Although the latter are essential in the interpretation of phylogeny, they cannot be regarded as direct reflections of evolutionary development, but rather as partial indicators, influenced by environment and by endoadaptation.

Within the textulariid foraminifera of the Upper Palaeozoic, the test wall is the most important biocharacter, although chamber form and pattern appear dominant in the relationship of the several bioseries. Other biocharacters, including apertural form and pattern, are of secondary importance in the analysis of the evolution of the group.

Test wall

This biocharacter may be described in terms of its structure (composition and texture) and its relative thickness. The latter shows a variation that can be correlated with test size on the one hand and wall structure on the other. Thus, Visean palaeotextulariids having a multi-layered type of wall possess a relatively thicker wall than contemporary forms, of approximately the same size, that have a uni-layered structure. (The term "palaeotextulariid" is here restricted to the forms referred hereunder to the Palaeotextulariidae.) Again, the relative thicknesses of different layers may vary within one type of compound structure. In contrast, the Namurian palaeotextulariids often exhibit variations in wall thickness that can be correlated directly with changing size. Reitlinger (1950) has used the bioseries of wall thickness as one of the basic criteria in his classification of *Climacammina* and other allied genera.

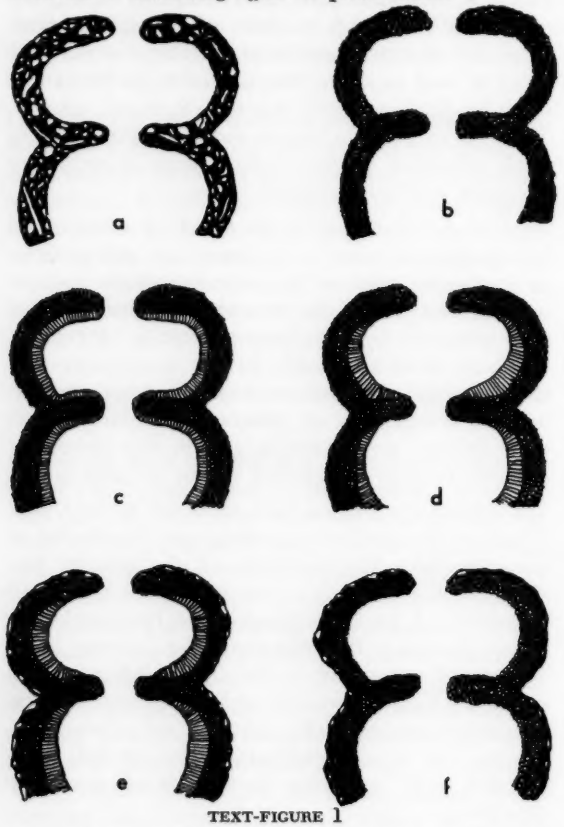
The fundamental importance of wall structure, and the various types present in foraminiferal tests, have been described by Glaessner (1945), and Wood (1949*a*). The former lists two types, the granular calcareous and the fibrous, that are peculiar to Upper Palaeozoic representatives, and notes the inadequacy of present knowledge of these structures. Carboniferous and Permian textulariids exhibit five different types of wall structure that can be regarded as primary conditions directly due to cytoplasmic activity. The wide variation in texture and composition seen in fossil specimens is due to the effects of secondary alteration on these five basic types.

Agglutinate: The test is composed of adventitious foreign material, such as quartz grains and particles of iron oxide, collected from the immediate environment during growth and formed into a semi-rigid or rigid structure by a varying proportion of cement, which is secreted directly by the protoplasm (see text-figure 1a). The cement is usually calcareous but may be ferruginous or siliceous. This structure is often defined as arenaceous, a term that should be confined to tests constructed wholly of sand grains.

The agglutinate test has been identified in the Upper Palaeozoic by numerous workers, and is recorded as occurring from the Cambrian to the present day. However, there is little doubt that only a very small proportion of the Carboniferous and Permian foraminifera possessed this structure. The concept of its widespread occurrence in the Upper Palaeozoic accepted by Brady, Cushman, and others was based on a misinterpretation of the granular calcareous structure and the outer agglutinate coating, as well as on the failure to recognise the effects of secondary alteration.

It would seem that this type forms the major element in the wall of only two groups of Upper Palaeozoic textulariids, those referable to *Textularia* and to *Bigenerina*. The present records of these genera in the Carboniferous and Permian are based largely on species requiring detailed petrographic analysis of the wall structure. It may well be the case that this type does not occur as a major element of test-wall construction in Upper Palaeozoic textulariids.

Granular calcareous: This structure is formed of equidimensional subspherical granules of calcite, of small dimensions, arranged in an irregular manner and closely packed together (see text-figure 1b-f and plate 1, figure 1). Within any one species, the size of the granules appears constant, but often there exists a variation in granule size between species. Wood (1949*a*) explains the characteristic dark appearance in transmitted light as being a result of the large number of granules, with random distribution and orientation, making up the thickness of the slide and producing numerous irregular interfaces that lead to loss of light. Detailed petrographic examination fails to reveal a cementing agent or perforations.



TEXT-FIGURE 1

Diagrams of various textures of wall structure present in Upper Palaeozoic textulariids as seen in thin section (relative size of granules and "fibres" much increased): a, agglutinate (cement in black, adventitious material white); b, granular calcareous; c, granular calcareous with complete inner lining of "fibrous" material; d, granular calcareous with inner "fibrous" layer in form of buttresses; e, granular calcareous with inner "fibrous" layer and outer agglutinate coating; f, granular calcareous with outer agglutinate coating.

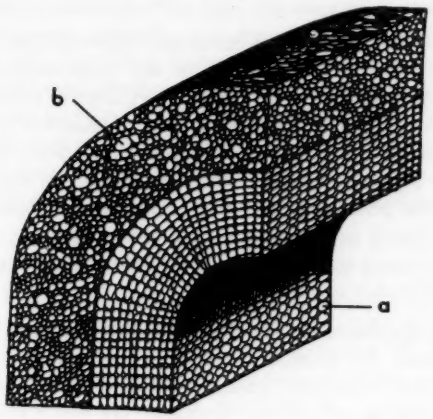
This is the dominant type of wall structure in the Upper Palaeozoic, and characterises the major group, the Endothyridea. Cummings (1955*b*) has indicated that it is not the result of an agglutinating activity of the cytoplasm but is produced by direct secretion. He therefore regards Cushman's "arenaceous" interpretation as incorrect. Nevertheless, secondary alteration may produce a texture that closely resembles the agglutinate condition (see plate 1, figure 2), which can be distinguished as secondary only by petrographic examination. This type is present in all palaeotextulariids as the main structural element, extending throughout the entire test, and provides the framework upon which layered tests are constructed (see text-figure 1b-f).

"Fibrous": This structure has been regarded as layers of fibres of calcareous material arranged so that the long axes of the fibres are parallel. In transmitted light, the structure is seen as alternating light and dark, narrow parallel zones, which might be considered as fibres with or without intervening perforations. The length and thickness of the "fibres" seems related to the external form of the structure, and Rauser-Chernoussova (1936) maintains that there are several variants, the "fibrous" structure of *Bradyina* being distinct from that of *Archaediscus.*

This type occurs as an inner layer of the test wall in the palaeotextulariids. The form of this layer varies. It may be developed as a complete internal lining of the chamber, or it may be confined to a semicircular buttress-like body in the lateral or marginal parts of the chamber (see text-figure 1c-e).

Recent petrographic examination of well preserved palaeotextulariids from the British Lower Carboniferous shows that, whilst this type appears fibrous in character at normal magnifications, each so-called fibre is formed by an alignment of calcareous granules. These are indistinguishable in size and form from those of adjacent granular calcareous layers. Indeed, the sole distinction between these structural types in the palaeotextulariids lies in the random arrangement of granules in the granular calcareous layers and, in contrast, the orderly linear arrangement in the "fibrous" layers (see text-figure 2 and plate 1, figure 3).

The orderly arrangement of granules leads to a related arrangement of optical interfaces. There exist major zones of maximum optical interference, lying at right angles to the exterior surfaces of the "fibrous" layer, along the planes separating rows of granules. These will show dark in transmitted light. Related major zones of minimum optical interference occur along planes passing through the centres of the aligned



TEXT-FIGURE 2

Diagram showing the arrangement of granules in a compound palaeotextulariid wall: a, "fibrous" layer; b, granular calcareous layer (relative size of granules much increased).

granules, and these will show less dark in transmitted light. The alternation of parallel major zones produces the appearance of fibrous structure by an alternation of dark and less dark bands. The effect of a corresponding pair of major zones lying parallel to the exterior surfaces of the "fibrous" layer will be reduced to negligible proportions by various factors, including the obliquity of the zones to the plane of section and the displacement of granules in curved structures.

The recognition of the "fibrous" type as being composed of aligned granules explains an anomaly noted by several workers. In the fibrous structure of the Hyalina, each fibre is formed by a crystal elongated along the c-axis and, as a result of the parallelism of the fibres, they exhibit characteristic optical properties, e.g., the mimicking uniaxial interference figure. It has been noted previously that such optical properties are not present in the fibrous tests of the Palaeozoic forms. The explanation of this anomaly lies in the fact that the aligned granules of the "fibrous" type have a random optical orientation.

Although the "fibrous" tests of the Palaeozoic are both optically and structurally distinct from the true Hyalina, the problem concerning them may be related to that of granular forms grouped within the Hyalina, as discussed by Wood (1949*a*, p. 241).

It is obvious that the term "fibrous" is misleading and largely incorrect. Its retention in this paper is a temporary expedient, pending the completion of the revision of the wall structure of Palaeozoic foraminifera.

A "fibrous" element is found in the tests of many palaeotextulariids, and it appears to have a fundamental significance in the bioseries. Reitlinger (1950) recognised two distinct groups of palaeotextulariids on the basis of different forms of "fibrous" layers, and these appear to have stratigraphic importance.

External agglutinate coating: Several authors have described the wall structure of the palaeotextulariids as arenaceous. Many have based their conclusions on the nature of the exterior of the test, including observations of a granular or roughened outer surface, or of the occurrence, on the exterior, of particles of larger size than the normal material of the wall, or of the presence of quartz grains projecting from the general surface. The nature of this external surface is largely dependent on secondary alteration and the environment of deposition. Thus, unusually large particles on the exterior surface may be regions of recrystallisation, and patches of quartz may result from partial silicification of the host sediment.

In spite of the large numbers examined, no evidence of an external agglutinated coating has been observed in any of the British palaeotextulariids. Nevertheless, the evidence from extra-British areas, notably that of Reitlinger (1950), shows that this does occur. In forms possessing a relatively thick wall, adventitious material may be incorporated separately, in patches, or as a coating on the outer surface of the granular layer (see text-figure 1e-f). Such a feature is not unknown in the Endothyridea, being described by Cummings (1955*a*) in the case of the Bradyininae and *Endothyranopsis*. The occurrence of this type appears to be limited to the large palaeotextulariids of the upper Visean and Namurian.

Multiple: The layered form of test wall is common within the Endothyridea, and three of the types described above (granular calcareous, "fibrous," and external agglutinate coating) are found as units in the following combinations that occur in the palaeotextulariids:

a. Granular calcareous alone (see text-figure 1b).
b. Granular calcareous with an inner "fibrous" layer (see text-figure 1c-d).
c. Granular calcareous with an inner "fibrous" layer and an external agglutinate coating (see text-figure 1e).
d. Granular calcareous with an external agglutinate coating (see text-figure 1f).

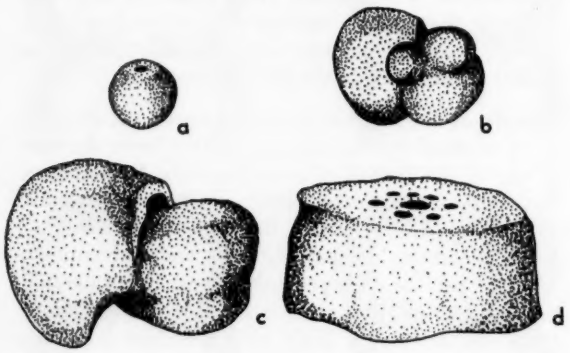
The relative thicknesses of the layers of each type present in these combinations vary between genera and within genera. The pattern of these changes, when

reviewed in the bioseries, appears to possess a value in interpretations of phylogeny.

There is little doubt that resorption of the material of the wall takes place in the palaeotextulariids. In several Tournaisian species of *Palaeotextularia,* adult forms exhibit foreshortened septa and wide septal openings in the nepionic and neanic stages. Such features are not present in juvenile forms and therefore must have been brought about by resorption in the late neanic or early ephebic growth stage. Similar evidence of resorption is to be found in *Cribrostomum* (see text-figure 5).

Chamber form

The various conditions of this biocharacter present in the palaeotextulariids are summarised in text-figure 3.



TEXT-FIGURE 3

Diagram of the conditions of chamber form in palaeotextulariids: a, spherical form of the proloculum; b, spherical form of chambers of the "circular" stage (relative sizes of 3a and 3b much increased); c, lunate form of biserial chambers; d, cylindrical form of uniserial chambers.

Fundamentally, the bioseries of chamber form is an expression of volume increment and is subordinated almost completely to the bioseries of the chamber pattern. Thus, the change from a spherical shape to a lunate form accompanies the change from the "circular" to the biserial pattern, and the change from the lunate to the cylindrical form occurs with the assumption of the uniserial pattern. Indeed, the relationship between chamber form and chamber pattern is so close, in the case of the palaeotextulariids, that they must be regarded as units of one bioseries. The morphogeny revealed by this is a direct reflection of the volumetric increase of protoplasm that occurs in the phylogeny of the stock. Such increases in the relative amount of protoplasm are a common feature of foraminiferal evolution.

Chamber pattern

Although the biocharacter of the test wall is of prime importance in the analysis of the palaeotextulariids, its expression is partly lost in morphogeny because of the dominance of the biocharacter of chamber pattern. The latter falls into several well defined patterns, and their sequence partly illustrates both the ontogeny and the phylogeny of the group. These patterns may be defined as conditions of the biocharacter, under terms based on the genus whose adult stage illustrates the chamber arrangement:

Pre-palaeotextularioid: The spherical proloculum is followed by a small number of spherical or subspherical chambers, gradually increasing in size and arranged in a "circular" manner (see text-figure 5a). The coiling is described as "circular" because its exact nature is unknown. It may be planispiral or trochospiral. This condition is seen in the nepionic stage of *Palaeotextularia diversa* (Chernysheva).

Palaeotextularioid A: The chambers are arranged in a biserial pattern and show a high degree of overlap, especially about the axial plane, so that the septa extend over the axis (see text-figure 5b-c). This condition is shown by the neanic and ephebic stages of *Palaeotextularia longissima* (Reitlinger) and by the nepionic stage of *Climacammina longissimoides* (Lee, Chen, and Chu).

Palaeotextularioid B: The chambers are arranged in a biserial pattern but show little or no overlap, with foreshortened septa and wide septal openings (see text-figure 5e-f). This condition may be seen in the ephebic stage of *Palaeotextularia grandis* (Reitlinger), and all gradations exist between it and the palaeotextularioid A condition.

Resorption of the wall often leads to a secondary development of this condition, as in the neanic stage of *Cribrostomum textulariforme* Möller and the nepionic stage of *Climacammina elegans* (Möller). In such instances, the chamber pattern is not a true record of ontogenic development.

Cribrostomoid A: This condition shows the final chamber of a biserial series somewhat inflated, asymmetrically placed with reference to the axis of earlier development, and extending over the terminal faces of the two preceding chambers of the biserial series (see text-figure 5g-i). It is typified in the ephebic stage of *Cribrostomum textulariforme* Möller, and is present in the neanic stage of *Deckerella laheei* Cushman and Waters.

Cribrostomoid B: It would seem that this is the ultimate stage of a gradational series from the cribro-

stomoid A condition. The final chamber of the biserial series extends laterally over the whole terminal area of the two preceding biserial chambers, and has become uniserial in alignment as well as cylindrical in form (see text-figure 5k). This condition is seen in the ephebic stage of *Cribrostomum attenuata* Harlton and in the neanic stages of *Climacammina magna* Roth and Skinner and *Climacammina elegans* (Möller).

Climacamminoid: The final chambers are arranged in a uniserial series. They range in number from two to six and have a cylindrical form (see text-figure 5n-q). When this condition is present as the ephebic stage of an individual, the number of uniserial chambers minus one (that being the equivalent of the cribrostomoid B condition) is indicated in parentheses. Thus, a specimen of *Climacammina* representing the adult condition of a species and possessing four uniserial chambers would be identified as climacamminoid (3). This pattern is present in the ephebic stage of *Deckerella clavata* Cushman and Waters and in the nepionic stage of *Cribrogenerina wysogorskyi* (Volz).

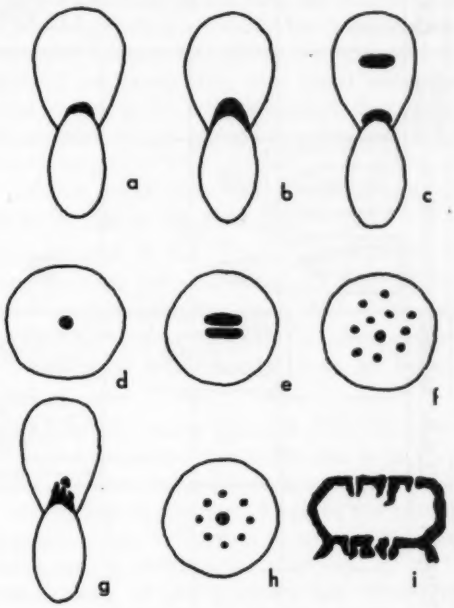
Cribrogenerinoid: This is the ultimate stage of a gradational series from the climacamminoid. In this stage, the uniserial chambers number seven or more and often show a distinct increase in width during growth (see text-figure 5w-z). The ephebic stage of *Cribrogenerina sumatrana* (Volz) illustrates this condition.

The several conditions listed above form a bioseries that runs from the pre-palaeotextularioid to the cribrogenerinoid pattern. The expression of this bioseries is so strong that it has led to an oversimplified interpretation of the morphogeny. Consideration of other bioseries in relation to that of chamber arrangement indicates that the latter alone does not provide a complete basis for phylogenetic interpretation, although it does illustrate the evolution of the palaeotextulariids in a general manner. Here too, the bioseries is a close reflection of the fundamental trend toward an increase of protoplasmic content.

Apertural form and arrangement

Both the test wall and the chamber form and pattern can be related directly to the protoplasm, the former to secretory and selective activities, and the latter to the shape and volume. In contrast, the form and arrangement of the aperture has a much more obscure relationship to the cytology and physiology of the animal. As a result, the value of this biocharacter in the classification of the foraminifera is questioned by many, who maintain that its variability bears little or no relationship to significant metabolic processes. Studies based on living foraminifera, such as those of Jepps (1942) and Myers (1943), reveal the inadequacies of such arguments.

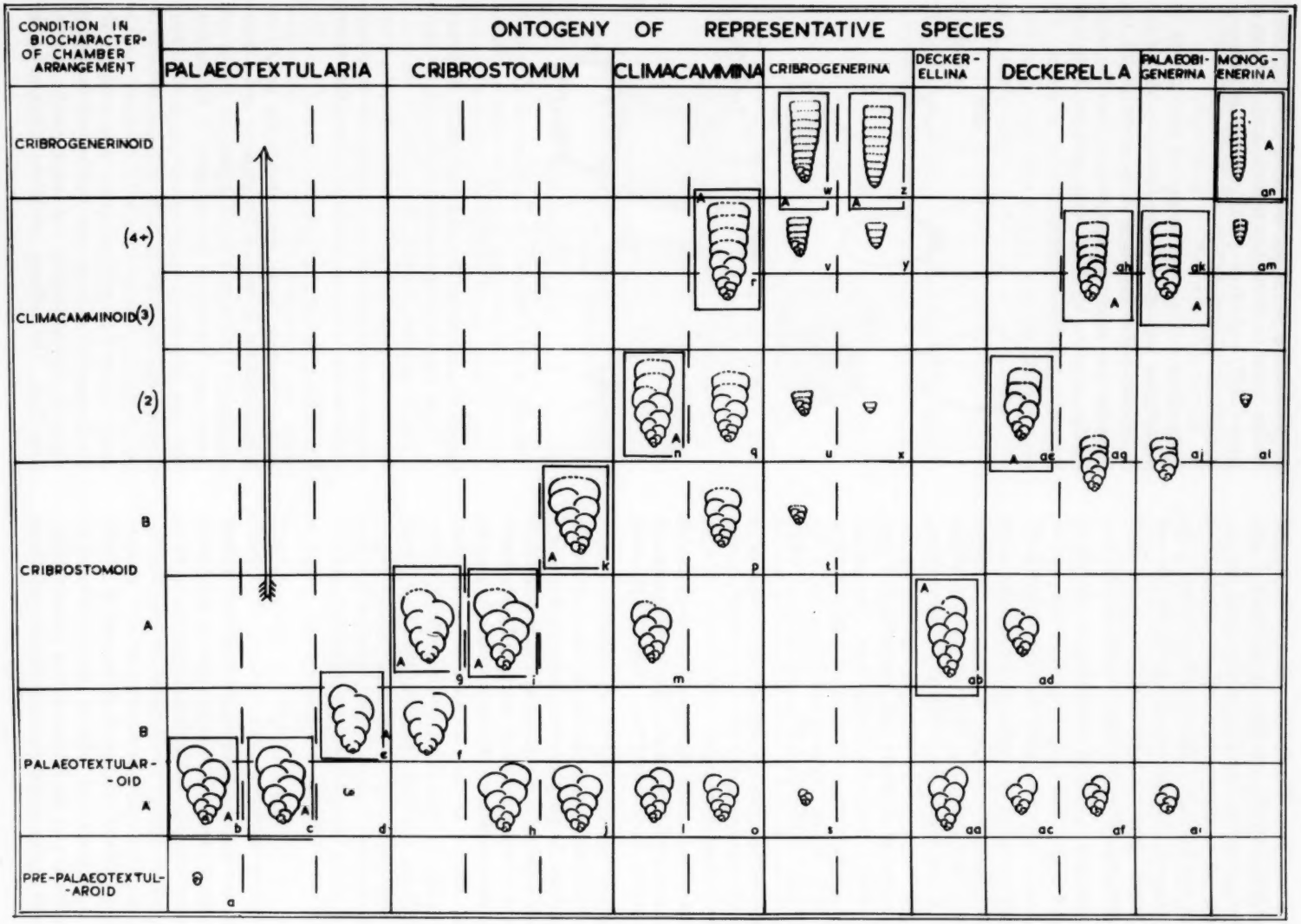
The various conditions of form and arrangement of the aperture present in Upper Palaeozoic textulariids are summarised in text-figure 4. In general terms, the bioseries may be regarded as passing from the single slit-like aperture to the double apertural form and thence to the cribrate character.



TEXT-FIGURE 4

Diagram illustrating the form and arrangement of apertures in Upper Palaeozoic textulariids: a, low slit; b, lunate; c, double condition present in *Deckerellina;* d, circular; e, double condition present in *Deckerella;* f, irregularly cribrate; g, incipient cribrate; h, regularly cribrate; i, vestibular siphons with irregularly cribrate condition, as seen in section.

Such a sequence is well illustrated in the series from *Palaeotextularia* through *Cribrostomum* and *Climacammina* to *Cribrogenerina*. The low-slit and lunate forms occur throughout the ontogeny of *Palaeotextularia,* are present up to the neanic stage in *Cribrostomum,* and are confined to the nepionic and embryonic stages of *Climacammina* and *Cribrogenerina*. The double apertural conditions occur very rarely in the neanic stage of *Cribrostomum* and in the late nepionic stage of *Climacammina,* but are normally omitted from both. The cribrate conditions characterise the



TEXT-FIGURE 5

neanic and ephebic stages of *Climacammina* and *Cribrogenerina*. Since this sequence corresponds closely with the stratigraphic distribution of the genera, it is assumed that the bioseries is a direct guide to the phylogeny. But the recognition of the incipient cribrate condition, and the spasmodic occurrence of the double apertural condition in *Cribrostomum* and *Climacammina*, are anomalies which indicate that the bioseries is not a complete reflection of the evolution of the group. This conclusion is supported by other anomalies in the *Deckerellina–Deckerella* and *Palaeobigenerina–Monogenerina* groups.

Septal characters

Within the Upper Palaeozoic textulariids, the internal septa exhibit wide morphologic variation both between species and in individual specimens. The nature and pattern of this variation appears to have classificatory value. When seen in axial section, the septa may have a straight, curved, or tangential alignment and a tapering, spatulate, ribbed, axe-shaped, or rectangular outline. All combinations of form unite with the varieties of wall structure to present a large number of septal types.

Although this biocharacter does have classificatory value, its significance is small. As an original terminal face, during the growth of the textulariid, the septum is the resultant of the interplay of the wall structure with the chamber form and arrangement on the one hand, and of the apertural form and arrangement on the other. It should be considered, therefore, as the product of the interaction of several bioseries and not as the expression of a fundamental trend.

DIAGENETIC ALTERATION AND ITS SIGNIFICANCE

One of the earliest acknowledgments of the effect of diagenetic alteration and compaction of the host sediment on the morphology and hence on the classification of Upper Palaeozoic foraminifera was made by Galloway (1933). More recently, Cummings (1955*b*) has outlined the methods of alteration and distortion present in British Lower Carboniferous assemblages. The present study of the textulariids provides numerous illustrations of such methods. Only those that have special significance in the textulariids, or those which are new, are presented.

Recrystallisation of the granular calcareous wall structure often leads to the formation of isolated and irregularly shaped particles of calcite or allied secondary products of larger grain size than the primary granules (see plate 1, figure 2). Usually these are scattered in an irregular manner throughout the wall, and in free weathered specimens they may stand out from the general surface of the test. As a result, they have been misinterpreted as the adventitious material of an agglutinate structure. The oriented clear grains within the granular layer mentioned by Reitlinger (1950) seem to be due to the same phenomenon.

Recrystallisation of the "fibrous" layer results in the production of an irregular mosaic of clear calcite that is often indistinguishable from that of the matrix. Secondary alteration may lead, therefore, to the misinterpretation of multi-layered tests as being unilayered.

Replacement also takes place in British Lower Carboniferous textulariids. Generally, this is in the form of dolomitisation, but in Scottish areas the process of iron enrichment is common. Thus, in the case of the microfauna from Wilkieston Quarry, Fife (see remarks under *Cribrostomum scoticum*, n. sp.), the original calcite of the granules has been replaced largely by ferrodolomite, with or without a varying proportion of limonite. The latter is itself a replacement product after siderite. This is a rather rare replacement process in the foraminifera, and results in the textulariid tests becoming roughened, extremely dark in colour, and almost opaque in thin section. It accompanies the iron-enrichment of the host sediment, which often leads to the production of ochreous limestones in Scottish areas.

TEXT-FIGURE 5

Chart showing the various sequences of conditions of chamber form and pattern in the ontogeny of representative species of the Palaeotextulariidae, as seen in axial section: A, adult condition; arrow indicates direction of ontogenic development; a-b, as seen in *Palaeotextularia diversa* (Chernysheva); c, as seen in *Palaeotextularia longissima* (Reitlinger); d-e, as seen in *Palaeotextularia grandis* (Reitlinger); f-g, as seen in *Cribrostomum textulariforme* Möller; h-i, as seen in *Cribrostomum bradyi* Möller; j-k, as seen in *Cribrostomum scoticum* Cummings, n. sp.; l-n, as seen in *Climacammina aljutovica* Reitlinger; o-r, as seen in *Climacammina antiqua* (Brady); s-w, as seen in *Cribrogenerina wysogorskyi* (Volz); x-z, as seen in *Cribrogenerina sumatrana* (Volz); aa-ab, as seen in *Deckerellina istiensis* Reitlinger; ac-ae, as seen in *Deckerella laheei* Cushman and Waters; af-ah, as seen in *Deckerella clavata* Cushman and Waters; ai-ak, as seen in *Palaeobigenerina cucumis* Lange; al-am, as seen in *Monogenerina atava* Spandel; diagrams of some forms enlarged.

Partial or complete silicification of the wall structure has been noted in palaeotextulariids from several Scottish localities. All such replacement phenomena may produce an "arenaceous" appearance of the test wall.

Compaction of the host sediment and consequent distortion of the test during fossilisation have led to several misinterpretations of the morphology of the palaeotextulariids. Brady (1876) considered the initial part of *Climacammina* as being trochospirally coiled, and hence included the genus within the Trochamminidae. The trochospiral appearance is due to the crushing of biserial chambers along the axis of the test.

ONTOGENY OF THE PALAEOTEXTULARIIDAE

The palaeotextulariid test lends itself to the study of ontogeny and the recapitulatory theory, because of the fact that all growth stages, from embryonic to ephebic, may be retained with little or no alteration within the test. Ontogenic development is important as a guide to the distinction of juvenile and adult individuals in the Palaeotextulariidae, but is even more important in the morphologic classification of the group. Several authors, such as Cushman (1928*a*) and Schubert (1907), have implied that ontogeny recapitulates phylogeny, and have employed this concept as the basis of their classifications.

Palaeotextulariid ontogeny may be described in terms of the successive conditions of the biocharacters as arranged from the initial proloculum to the final portion of the test. This requires both study of the external form and thin-section examination of the internal structure, particularly that of the axial plane. It also requires a full recognition of the effects of secondary alteration in the modification of structural elements.

Within an individual adult specimen, the successive conditions of the three fundamental palaeotextulariid biocharacters (test wall, chamber form and pattern, and apertural form and pattern) provide the basis for a detailed analysis of the ontogeny. Thus, such a specimen of *Cribrostomum* may show an initial biserial condition with slit-like aperture, passing to the cribrostomoid A condition with a multiple aperture and with the wall structure exhibiting a relative increase in thickness without structural change throughout the test. The ontogeny of this specimen is defined in terms of the successive conditions of the various biocharacters.

The value of these biocharacters in description varies, depending upon their rate of change and their dominance in relation to other biocharacters. In single adult specimens, that of wall structure shows little variation. Some species of *Climacammina* and *Deckerella* possess a compound wall structure with an inner "fibrous" layer in the adult portion, and a uni-layered granular calcareous wall in the initial part of the test. Other palaeotextulariids exhibit a variation of wall thickness during ontogeny. The great majority, however, show a constancy of both structure and relative thickness throughout growth, and this, together with the effects of resorption, reduces the biocharacter's value in ontogenic analysis. Nevertheless, this constancy is considered to be of major importance in the morphologic classification and phylogenetic interpretation of the group (see introductory remarks under "Systematic Revision").

When the chamber form and pattern in any individual adult specimen of the Palaeotextulariidae are examined, several conditions of the biocharacter are usually present. These provide, by their order and variety, an almost complete basis for the description of ontogeny, since this is the dominant biocharacter throughout the greater part of the evolution of the group. Furthermore, the succession of these conditions during ontogeny is often the same as that in part of the inferred bioseries. Thus, the biserial to uniserial succession of the bioseries is exhibited in the growth of any individual adult form of *Climacammina antiqua* (Brady). This close relationship between the ontogenic succession of conditions of chamber pattern and the inferred bioseries exists throughout the whole group (see text-figure 5). It is this relationship, when reviewed against the background of the stratigraphic sequence of genera, that has led to the interpretation of the phylogeny as being one of simple recapitulation. The anomalies listed below indicate, however, that this close similarity may be misleading.

The biocharacter of apertural form and arrangement has a variable value in the interpretation of palaeotextulariid ontogeny. The only variation of condition present in the ontogeny of individual adult specimens of the *Palaeobigenerina–Monogenerina* group is the change of form from lunate to circular. This is directly dependent on a change of chamber pattern, and the single nature of the aperture remains throughout. Hence the biocharacter has no value in ontogenic interpretation in this instance. Within the *Deckerellina–Deckerella* group, the ontogeny may be partly described in terms of the change from the single to the double apertural condition. Since this change is present throughout the group, it is inadequate for most purposes. As indicated above, successive condi-

tions of this biocharacter are present in the *Palaeotextularia–Cribrogenerina* group. In an individual adult specimen of such a genus as *Climacammina*, there may occur a sufficient number of these successive conditions to describe the ontogeny in terms of the apertural form and arrangement. Thus, Cushman and Waters (1928*a*) identified the successive apertural conditions of *Climacammina cushmani* (Harlton), and the ontogeny of a specimen may be described in the series low-slit — lunate — incipient cribrate — irregularly cribrate—regularly cribrate. Such sequences differ between species, and operate independently of those of chamber form and pattern. Furthermore, in many instances they do not reflect the sequence of the bioseries. In other genera of this group, such as *Palaeotextularia* and *Cribrogenerina*, there is little or no variation of apertural form, either within species or within individual adult specimens. Hence the importance of this biocharacter in ontogenic analysis differs throughout the Palaeotextulariidae.

A review of the ontogeny based on individual adult specimens of numerous species reveals many anomalies between the pattern of successive conditions of growth and the inferred bioseries of the three main characters. One or two of these anomalies may be cited as illustrations. Some species of *Climacammina* and *Deckerella* possess a cribrostomoid A condition in the early neanic stage, but others have this replaced by a cribrostomoid B condition (see text-figure 5l-r). This is not a true reflection of the bioseries, which shows the cribrostomoid B condition as a gradual development from the cribrostomoid A, and is exemplified in successive populations of *Cribrostomum*. Again, the ontogenic sequence of apertural conditions varies between species of *Climacammina*, and is not always in accordance with that of the bioseries. Finally, the ontogeny of *Deckerella* shows a greater similarity in the successive conditions of chamber form and pattern to that of *Climacammina* than it does to that of *Deckerellina*, even though the sequences of apertural form in the latter and in *Deckerella* are almost identical.

The significance of these anomalies lies in their indication of discrepancies between the ontogenic sequence of conditions and the various bioseries. The pattern of ontogeny is developed on several biocharacters, each of which may show different expressions in the different combinations of the successive conditions. Hence, ontogeny cannot be described completely in terms of the bioseries of one character, however dominant that one biocharacter may be in relation to the others. Nor is it to be expected that the pattern of ontogeny and of the bioseries will be identical. Palaeotextulariid ontogeny is closely expressed in parts of the bioseries of chamber form and pattern. This is due to the dominance of that biocharacter throughout the greater part of the evolution of the stock. Where that dominance is reduced, the influence of other bioseries leads to discrepancies such as those cited above. These also illustrate the necessity of considering the several bioseries as an anastomosing plexus and not as separate units operating independently.

One of the fundamental problems in the analysis of the palaeotextulariids, referred to above, arises from the repetition of the same chamber pattern in the ontogeny of the successive genera of the family. This is illustrated in text-figure 5, where the palaeotextularioid A condition is present in the ephebic stage of *Palaeotextularia*, the neanic stage of *Cribrostomum*, and the nepionic stage of five other genera.

Where an assemblage of palaeotextulariids is being studied, the ontogenic stage may be identified by population analysis and detailed morphologic comparison. The solution to the problem is readily forthcoming in such instances.

In the case of palaeotextulariids occurring as individual specimens, free or in thin sections of limestones, the technique of population analysis cannot be employed, however. Nevertheless, the identity of the specimen can often be established by detailed morphologic comparison with the sequence and character of the known ontogenic stages of the various genera. Thus, a specimen exhibiting the palaeotextularioid A condition may be referable to any one of seven genera, when the chamber pattern alone is considered. When other biocharacters, such as the septal form, the apertural form and pattern, and especially the structure and thickness of the wall, are reviewed and related to the known sequence in the ontogeny of the various genera, the identity of the specimen can often be established conclusively. By a documentation of the bioseries, and of the successive conditions present in the ontogeny of the genera, individual specimens may be identified to generic rank in many cases.

Many palaeotextulariid species have been described without reference to population analysis, often on the basis of one or two specimens, and others have been based on thin sections in limestone. In some cases, later workers have identified the adult condition of such species by population analysis, and thus have ensured their correct generic placing. Using the techniques outlined above, this present study has verified or revised the generic placing of a further number of

these species. Nevertheless, some still remain, including several based on imperfect or oblique thin sections. In these, the actual ontogenic stage of the described form cannot be established, and hence they must be regarded, in an arbitrary fashion, as expressions of the adult condition and classified accordingly.

SYSTEMATIC REVISION

The value of the wall structure in the morphologic classification of the foraminifera lies in the fact that it is an almost direct reflection of cytoplasmic function and hence of the natural grouping. For this reason, it is accepted as the fundamental biocharacter in such modern classifications as those of Galloway (1933), Glaessner (1945), and Cushman (1948), and a detailed assessment of this classificatory value, using petrographic methods, has been given by Wood (1949*a*). Its importance is as great in the Palaeozoic foraminifera as it is in later forms, and must be reviewed in full awareness of the effect of secondary alteration on the preservation of the wall.

Essentially, the test wall results from two cytoplasmic activities, those of selection and secretion, as already indicated by Cummings (1955*b*). Although these may act together to produce the agglutinate type of structure, their very nature indicates differing metabolic functions. Furthermore, the secretory activity is composed of several distinct processes, each producing a distinct material, such as calcareous cement, granules, and "fibres."

In modern classifications, these processes and functions are considered so fundamental and so distinct that the same geometric form may be referred to two or more genera, in unrelated families and superfamilies, if it shows two or more types of wall structure. Thus, a test in the form of a simple undivided planispirally coiled tube may be placed in *Ammodiscus, Cornuspira,* or *Spirillina,* depending upon the nature of the primary condition of its wall structure.

It is surprising, therefore, to find that several classificatory groups of Palaeozoic foraminifera contain genera possessing radically different types of test wall. Thus, in the case of the textulariid foraminifera, it has been common practice in the past to group together such genera as *Textularia* and *Climacammina;* the former has a typically simple agglutinate test, whilst the latter possesses a test of multiple structure, "fibrous," granular calcareous, and agglutinate, in varying combinations.

Cushman (1928*a* and 1948) grouped them together on the basis of a common or related growth plan, and considered them dominantly agglutinate. Glaessner (1945), however, noted that such a grouping in the Textulariidae was a provisional measure.

In contrast, Galloway (1933) stated that all Palaeozoic textulariids possessed a multiple wall structure, and placed them in the Palaeotextulariinae. In so doing, he acknowledged the fundamental difference between the multiple structure and the simple agglutinate wall of *Textularia,* but maintained that the basic difference lay in their mode of origin, the Textulariinae arising from a planispiral ancestor and the Palaeotextulariinae "probably from a staggered species of *Cayeuxina.*" Since this interpretation of origin as the basis of the subdivision could not be substantiated, he retained the two different groups together in the Textulariidae until their separate origin was proved.

Later work has shown that Galloway's interpretation of textulariid phylogeny is largely incorrect, and that representatives of both *Textularia* and the Palaeotextulariinae occur in the Palaeozoic. Nevertheless, in this revision, his subdivision of the Palaeozoic textulariids into two groups on the basis of wall structure is developed into the proposed classification of Textulariidae and Palaeotextulariidae, the former being referred to the Lituolidea and the latter to the Endothyridea.

Such a classification recognises the multiple structure as a distinct type, of equal genetic significance with, and of the same fundamental importance as, the hyaline or the porcellanous. This is no new departure. Glaessner (1945) has already noted the structure as a distinct type, and the recognition of such families as the Fusulinidae is dependent in part on this distinction. The present revision would seem to be a logical and necessary alteration in the classification of the group, where, hitherto, similarity or identity of chamber form and pattern have been allowed to override significant differences in wall structure.

Much of the past confusion in the systematics of the Palaeozoic textulariids has arisen as a result of failure to appreciate the effects of secondary alteration, lack of detailed petrographic examination of the microstructure of the wall, and lack of appreciation of the causes of variability in chamber form in thin-section analysis.

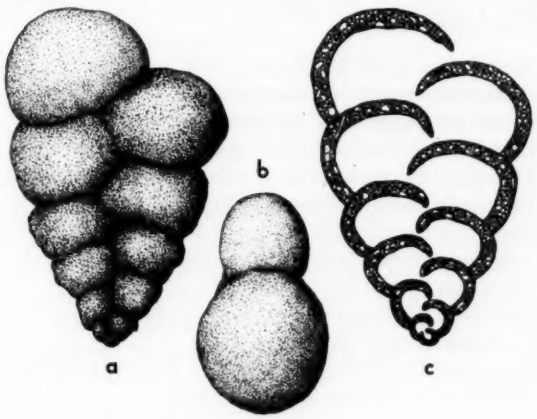
This work is confined to a revision of the Upper Palaeozoic textulariids at generic rank and a review of described species within the genera, together with descriptions of new species and a revision of previously described species from the British Lower Carboniferous.

Superfamily LITUOLIDEA

Family **Textulariidae**

Tests free, rarely attached, elongate; planispiral in early part and later biserial, or biserial throughout, or biserial in early part and later uniserial, or uniserial throughout; wall agglutinate, arenaceous, with varying proportions of cement, usually calcareous; aperture slit-like or lunate, at base of terminal face on inner margin, or a row of pores, or terminal and round, or fissurine. Lower Palaeozoic to Recent.

Within the Upper Palaeozoic, this family is represented by *Textularia*, in the main, although *Bigenerina* may be present. The status and systematic position of other genera such as *Spiroplectammina*, *Pseudopalmula*, and *Semitextularia* as Upper Palaeozoic forms are discussed below.



TEXT-FIGURE 6

Textularia sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen; c, longitudinal axial section.

Genus **Textularia** Defrance, 1824
Text-figure 6a-c

Clidostomum Ehrenberg, 1843.
Grammostomum Ehrenberg of authors (part).
Plecanium Reuss, 1862.
Pseudobolivina Wiesner, 1931.
Textilaria Ehrenberg, 1854, and other authors.
Textillaria Schwager, 1865.

Type species: Textularia sagittula Defrance, 1824.

Description: Test free, elongate, tapering, typically compressed, with a zig-zag sutural line between chambers on flattened surfaces; rectangular in cross section, with rounded or angled edges; early chambers in microspheric form sometimes planispirally coiled after a spherical proloculum, but usually the latter is followed immediately by alternating chambers arranged in a biserial plan; chambers numerous, closely appressed, later ones often inflated; chambers separated internally by septa formed by incurving of test wall, and these exhibit variable shape, curvature, and thickness; periphery smoothly rounded to lobulate; surface smooth or granular; wall composed of agglutinated adventitious material, usually quartz grains, with a varying proportion of calcareous cement, of an arenaceous texture and often perforate, especially in forms possessing a high proportion of cement; aperture a single circular or lunate opening, at or near base of terminal face of final chamber, on inner margin.

In thin section, representatives of this genus may be identified in axial section only, by the agglutinate nature of the test wall and the biserial chamber arrangement (see text-figure 6a-c).

Ontogeny: Arising from a simple spherical proloculum, the textulariids often exhibit a planispirally coiled nepionic stage in the microspheric form. In some, such as *Textularia sagittula* Defrance, this planispiral coiling is present also in the megalospheric generation. In the majority of species, however, the proloculum is succeeded immediately by a series of alternating chambers, increasing gradually in volume and arranged in a typically biserial pattern.

Species possessing a planispirally coiled nepionic stage occur at widely separated stratigraphic horizons and do not appear to be related phylogenetically. This may indicate polyphyletism in *Textularia*.

Comparison and affinities: The basic distinction between *Textularia* and *Palaeotextularia* lies in the difference of wall structure. Although they exhibit an almost complete identity of form, this morphologic dissimilarity warrants their separate recognition, in view of its fundamental significance.

Cushman (1928*a*) and others suggest that *Textularia* developed from *Spiroplectammina* by a progressive reduction of the initial planispiral stage of the latter. The presence of a planispirally coiled nepionic stage in some species of *Textularia* supports such a hypothesis. It is possible that the pattern of development of *Textularia* during the Mesozoic and Kainozoic was polyphyletic and of this nature.

In the case of Palaeozoic examples, however, such a saltatory process is considered unlikely. *Textularia* is recorded at various horizons from the Ordovician, and if these are correct, prior to the first appearance of *Spiroplectammina* in the Lower Carboniferous. Again, as Reitlinger (1950) suggests, Carboniferous species of *Spiroplectammina* bear a remarkable similarity of form to representatives of *Biseriammina* Chernysheva, 1941. It seems very likely that the common Upper Palaeozoic spiroplectamminids are derivatives of the Biseriamminidae and are not, as Cushman has suggested, ancestral to the Carboniferous textulariids. The Carboniferous spiroplectamminids can be distinguished from *Textularia*, on the one hand, and from

Mesozoic and Kainozoic species of *Spiroplectammina* on the other, by differences of wall structure that may prove to be of classificatory significance.

The genus *Volvotextularia* Termier and Termier, 1950, from the Upper Palaeozoic of Morocco, is in no way related to *Textularia* and is possibly a derivative of the Tetrataxinidae. The Pennsylvanian *Mooreinella* Cushman and Waters (1928*d*) and its possible synonym *Digitina* Crespin and Parr, 1940, of Permian age, possess a trochoid initial portion, which indicates an affinity to the Trochamminidae rather than to the Textulariidae. The wall structure and morphology of the Devonian genera *Pseudopalmula* Cushman and Stainbrook (1943), *Paratextularia* Pokorný (1953), and *Semitextularia* Miller and Carmer (1933) indicate the close relationship of these genera to the Upper Palaeozoic spiroplectamminids, and hence they may also be referable to the Biseriamminidae.

Horizon and facies: Textularia has not been recognised in the British Lower Carboniferous, and several workers, including Wood (1949*b*) and Pokorný (1953), have demonstrated that many of the Lower Palaeozoic records of *Textularia* are incorrect. Pending re-examination of the wall structure of many forms, the occurrence of *Textularia sensu stricto* in the Palaeozoic is to be questioned but not denied.

Revision of the Upper Palaeozoic records of *Textularia* is summarised:

A. Upper Palaeozoic species referable to *Textularia* sensu stricto:

There are no Upper Palaeozoic species that may be referred to *Textularia* without further study of the morphology of the type forms.

B. Upper Palaeozoic species that may be referable to *Textularia* sensu stricto:

Re-examination of the microstructure of the test wall and an assessment of the state of preservation may show that some of the following species should be placed in *Textularia* Defrance:

Textularia cf. *bradyi* (Möller) of Schellwien (1898);
Textularia cornuta Waters, 1928;
Textularia exidula Lee, 1937;
Textilaria eximia Eichwald, 1859;
Textularia "eximia Eichwald" of Cushman and Waters (1930) (*non* Eichwald);
Textularia "eximia Eichwald" of Crespin and Parr (1940) (*non* Eichwald);
Textularia exrayensis Cushman and Waters, 1927;
Textularia fuscalignensis Cushman and Waters, 1927;
Textularia multilocularis Reuss, 1861;
Textularia triticum Jones, 1850.

C. Upper Palaeozoic species not referable to *Textularia* sensu stricto, whose correct generic placing is known:

Galloway and Ryniker (1930) designated the type species of *Palaeotextularia* and revised some of the earlier records:

Textularia "textulariformis (Möller)" of Schellwien (1898) (*non Cribrostomum textulariforme* Möller, 1879) was designated as the type species of *Palaeotextularia* and renamed *Palaeotextularia schellwieni* Galloway and Ryniker, 1930;
Textularia grahamensis Cushman and Waters, 1927, was listed as *Palaeotextularia grahamensis* (Cushman and Waters).

As a result of the present revision, the following forms hitherto referred to *Textularia* are placed under *Palaeotextularia*:

**Textularia angusta* Reitlinger, 1950;
Textularia angusta var. *decurta* Reitlinger, 1950;
**Textularia angusta* var. *elongata* Reitlinger, 1950;
Textularia angusta var. *maxima* Reitlinger, 1950;
Textularia breviseptata (Lipina) of Reitlinger (1950);
Textularia bruta Reitlinger, 1950;
Textularia consobrina (Lipina) of Reitlinger (1950);
Textularia eofragilis Reitlinger, 1950;
Textularia fragilis Reitlinger, 1950;
Textularia gibbosaeformis Reitlinger, 1950;
Textularia grandis Reitlinger, 1950;
Textularia longiseptata (Lipina) of Reitlinger (1950);
Textularia longissima Reitlinger, 1950;
Textularia minutissima Reitlinger, 1950;
Textularia paracommunis Reitlinger, 1950;
**Textularia ponderosa* Reitlinger, 1950;
Textularia primitiva Reitlinger, 1950;
Textularia sumatrensis Lange, 1925;
Textularia thorax Lange, 1925;
Textularia vulgaris Reitlinger, 1950.

The specific and varietal names marked with an asterisk (*) have been indicated as preoccupied, by Thalmann (1952).

A further amendment resulting from the present revision is:

Palaeotextularia davisella Cummings, n. sp., based on *Textularia "gibbosa* d'Orbigny" of Brady (1876) (*non* d'Orbigny).

The following modifications should also be noted:

Textularia antiqua Brady, 1871, is here included, as the type species, in *Climacammina* Brady, 1876;

Textularia "eximia Eichwald" of Brady (1876) (*non* Eichwald) is here included, as a synonym, in *Cribrostomum "eximium* (Eichwald)" of Möller (1879);

"Textularia" communis (Möller) of Liebus (1931) is here included, as a synonym, in *Cribrostomum commune* Möller, 1879;

Textularia cuneiformis Jones, 1850 (*non* d'Orbigny, 1839), designated by Cushman (1928*b*) as type species of *Geinitzina* Spandel, 1901; recognised as a homonym by Brady (1876) and renamed *Textularia jonesi* Brady, 1876;

Textularia jonesi Brady, 1876, based on *Textularia cuneiformis* Jones, 1850 (*non* d'Orbigny, 1839); examination of the wall structure shows that this form cannot be referred to the Textulariidae and must be included in the Lagenidea; it follows that the genus *Geinitzina* must be considered a member of the Lagenidea.

D. Upper Palaeozoic species not referable to *Textularia* sensu stricto, but which require further study before the correct generic placing can be effected:

Textularia "eximia Eichwald" of Lee, Chen, and Chu (1930) (*non* Eichwald); this species is based on an oblique longitudinal section of a *Climacammina*, and has been included as a synonym of *Climacammina* sp. by Galloway and Spock (1933);

Textularia "eximia Eichwald" of Lee (1937) (*non* Eichwald), based on an oblique longitudinal section of a *Climacammina;*

Textularia "eximia Eichwald" of Lange (1925) (*non* Eichwald), based on an oblique longitudinal section of a *Climacammina;*

Textularia obusa Huzimoto, 1938; the description of this species by Huzimoto (1938) suggests that the form should be included in *Palaeotextularia.*

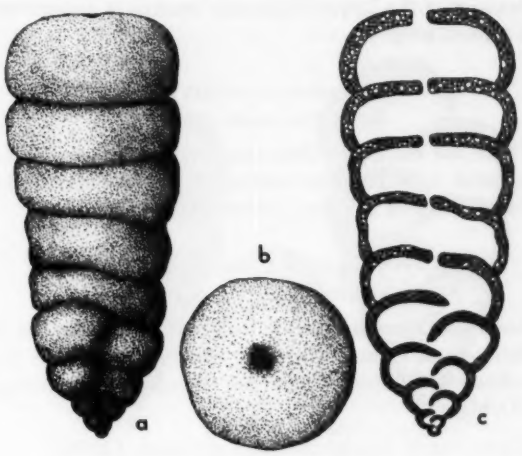
Genus **Bigenerina** d'Orbigny, 1826

Text-figure 7a-c

Gemmulina d'Orbigny, 1839 ("Gemmulines" d'Orbigny, 1826).

Type species: Bigenerina nodosaria d'Orbigny, 1826, designated by Cushman (1911).

Description: Test free, elongate, sharply tapering in early portion and gradually tapering or cylindrical in later portion; consisting of a spherical proloculum, followed by biserial overlapping chambers in neanic portion and a uniserial ephebic stage; sutures distinct and depressed; surface rough or granular; peripheral margin faintly lobulate, with circular or ellipsoidal cross section; wall usually thick, consisting of adventitious material, frequently quartz grains, bound by a calcareous cement into an agglutinated structure, with the proportion of cement varying greatly; aperture in the biserial stage a low lunate opening at the base of the terminal face on the inner margin, later terminal, simple, single and rounded, situated in the central region of the apertural face. In thin section, representatives of this genus may be identified, in axial section only, by the agglutinate structure of the wall and the characteristic chamber arrangement and sequence of apertural conditions (see text-figure 7a-c).



TEXT-FIGURE 7

Bigenerina sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen; c, longitudinal axial section.

Ontogeny: Cushman and Waters (1930) state that the earliest chambers of some forms are planispirally coiled in the microspheric generation, but that this is seldom the case in the megalospheric generation. Whilst this condition is present in Mesozoic and Kainozoic forms, there seems little or no evidence to show that it existed in Palaeozoic bigenerinids.

Comparison and affinities: The acceptance and validation of *Palaeobigenerina* in this present study radically alters the status of *Bigenerina* as a Palaeozoic genus. Previously, Cushman (1928*a*) and others placed all Palaeozoic and later forms having a bigenerinid chamber and apertural pattern in *Bigenerina,* irrespective of the nature of the wall structure. In contrast, Galloway (1933) placed all such Palaeozoic species in *Palaeobigenerina.* This revision shows that the great majority of Palaeozoic bigenerinids should be referred to *Palaeobigenerina* and to other genera of the Palaeotextulariidae. Nevertheless, there are a few species, such as *Bigenerina ciscoensis* Cushman and Waters (1928*b*), which may represent *Bigenerina* in the Upper Palaeozoic.

Horizon and facies: Bigenerina may be present in the Upper Palaeozoic as a very rare form confined to the sandy facies.

Revision of the Upper Palaeozoic records of *Bigenerina* is summarised:

A. Upper Palaeozoic species referable to *Bigenerina* sensu stricto:

There are no Upper Palaeozoic species that may be referred to *Bigenerina* without further study of the morphology of the type specimens.

B. Upper Palaeozoic species that may be referable to *Bigenerina* sensu stricto:

Re-examination of the test wall and an assessment of the state of preservation may show that some of the following species should be placed in *Bigenerina* d'Orbigny:

Bigenerina cf. *bradyi* (Möller) of Ozawa (1925);
Bigenerina ciscoensis Cushman and Waters, 1928;
Bigenerina hsukuanghsii Lee, 1937.

C. Upper Palaeozoic species not referable to *Bigenerina* sensu stricto, whose correct generic placing is known:

The revision of records by previous workers is as follows:

Bigenerina geyeri Schellwien, 1898, was listed as *Palaeobigenerina geyeri* (Schellwien) by Galloway (1933), and designated as the type species of the genus *Palaeobigenerina* Galloway, 1933;
Bigenerina sumatrana Volz, 1904, was listed as *Cribrogenerina sumatrana* (Volz) by Schubert (1907), and designated as the type species of the genus *Cribrogenerina* Schubert, 1907;
Bigenerina wysogorskyi Volz, 1904, was listed as *Cribrogenerina wysogorskyi* (Volz) by Schubert (1907).

The present revision leads to further amendments amongst earlier records, including:

Bigenerina perrodata Lange, 1925, is listed as *Palaeotextularia perrodata* (Lange);
Bigenerina elegans (Möller) of Schellwien (1898) is included, as a synonym, under *Climacammina elegans* (Möller);
Bigenerina milchi Volz, 1904, is listed as *Climacammina milchi* (Volz);
Bigenerina mitrata Trautschold, 1879, is listed as *Climacammina mitrata* (Trautschold);
Textularia (Bigenerina) patula Brady, 1876, is listed as *Climacammina patula* (Brady);
Bigenerina leonhardi Volz, 1904, is listed as *Cribrogenerina leonhardi* (Volz);
Bigenerina cucumis Lange, 1925, is listed as *Palaeobigenerina cucumis* (Lange);
Bigenerina perexigua Plummer, 1945, is listed as *Palaeobigenerina perexigua* (Plummer); examination of type material shows that this has undergone partial silicification, and the quartz grains are not considered primary;
Bigenerina sp. of Schellwien (1898) is listed as *Palaeobigenerina* sp.

D. Upper Palaeozoic species not referable to *Bigenerina* sensu stricto, but which require further study before the correct generic placing can be effected:

Bigenerina "triticum (Jones)" of Liebus (1932) (*non* Jones) may be placed in the genus *Palaeotextularia;*
Bigenerina yamadai Yabe, 1920; this species has been figured but never described.

Superfamily ENDOTHYRIDEA

Family **Palaeotextulariidae** Cummings, **new family**

Test free, elongate; chambers biserial throughout, or biserial in early part and later uniserial, or uniserial throughout, although the earliest part of the microspheric form of some species may be developed on a "circular" plan; wall layered, with a main granular calcareous element, an inner "fibrous" calcareous layer, and a thin, patchy external cover of adventitious material, in varying combinations and proportions; aperture slit-like or lunate, at base of terminal face on inner margin, or terminal and single, double or cribrate. Devonian(?), Carboniferous and Permian.

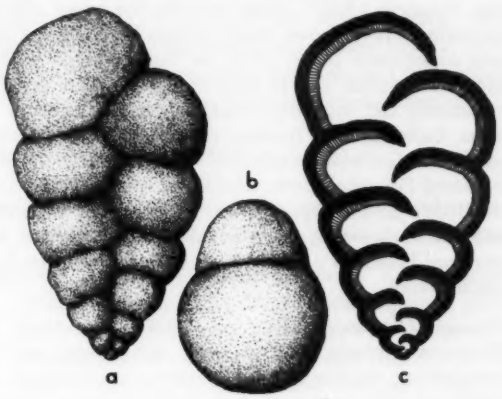
The characteristic wall structure of this family indicates its affinity to the Endothyridea and distinguishes it from the Textulariidae of the Lituolidea.

The origin of this family is unknown as yet, since it is in no way connected with the Textulariidae of the Palaeozoic. The earliest genus, *Palaeotextularia*, occurs in the lower Tournaisian, possibly in the Devonian also, and often shows a small circular arrangement of the nepionic chambers in the microspheric form of some species. This "circular" arrangement may be a result of planispiral or trochospiral coiling, no conclusive evidence having been obtained for either type. Hence the family may have arisen from some late Devonian endothyrid by the development of a biserial chamber pattern.

Within the Palaeotextulariidae there are grouped eight genera, distinguished from one another by differences in chamber pattern and apertural conditions. The arrangement of these genera is summarised in text-figure 8. It is possible that the genus *Monostomum*, listed by Mikhailov (1935) but undescribed, is based

CHAMBER ARRANGEMENT	APERTURAL CONDITION in ADULT		
	SINGLE	DOUBLE	MULTIPLE
UNISERIAL	Monogenerina		Cribrogenerina
UNISERIAL and BISERIAL	Palaeobigenerina	Deckerella	Climacammina
ONE ASYMMETRICAL CHAMBER and BISERIAL		Deckerellina	Cribrostomum
BISERIAL	Palaeotextularia		
BISERIAL and 'CIRCULAR'			

TEXT-FIGURE 8



TEXT-FIGURE 9

Palaeotextularia sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen; c, longitudinal axial section.

on forms referable to the Palaeotextulariidae. It must be regarded, however, as a *nomen nudum*.

The classification of the family summarised in text-figure 8 is based on that of Schubert (1907) and on that of Cushman (1928*a*), both of whom regarded this pattern as indicative of the phylogeny of the stock. It might be interpreted as three branches stemming from the biserial condition, each of which is characterised by a constancy of apertural condition whilst passing through successive stages of chamber arrangement. The anomalies noted in the present analyses of ontogeny and phylogeny, however, seem to indicate that this classification is strictly morphologic, reflecting the evolution of the group only in a very general manner. Rather than each genus being regarded as a natural unit, it should be considered as a common and often prevalent combination of bioseries within a plexus, which may be derived along different evolutionary channels, both by analogous and by homologous homeomorphy.

Genus **Palaeotextularia** Schubert, 1920
Text-figure 9a-c

Textularia Defrance. – Brady (1876) and other authors (in part).

Bigenerina d'Orbigny. – Lange (1925) and other authors (in part).

Type species: Palaeotextularia schellwieni Galloway and Ryniker, 1930 (based on *Textularia "textulariformis* (Möller)" of Schellwien (1898), *non Cribrostomum textulariforme* Möller, 1879), designated by Galloway and Ryniker (1930).

Description: Test free, elongate, tapering, typically compressed, with a triangular outline in side view showing zig-zag suture, and a triangular or rectangular outline in end view, with rounded or angled edges; circular to rectangular in cross section; biserial arrangement of numerous alternating chambers arising from small spherical proloculum and developed on a straight or slightly curved axis; in some microspheric forms and very rarely in some megalospheric forms, the earliest chambers are coiled in a "circular" manner; chambers simple, not labyrinthic, often closely appressed, later ones sometimes inflated; sutures usually distinct and depressed; internally, septa show variation in curvature, shape, and thickness and are formed by incurving of test wall; periphery smooth to faintly lobulate; surface smooth to rough, or granular; wall composed of a main granular calcareous element showing dark in transmitted light, with or without an inner "fibrous" layer of varying form showing yellowish or clear in transmitted light, and rarely with a thin, impersistent external cover of embedded adventitious material; aperture a single circular to semilunate opening, along or slightly above the base of the last-formed chamber, on the inner margin.

In thin section, representatives of this genus may be identified, in axial section only, by the characteristic wall structure and the condition of the chamber arrangement, which is palaeotextularioid A or B, with or without pre-palaeotextularioid (see text-figure 9a-c). The distinction of the adult *Palaeotextularia* from the juvenile forms of the more advanced genera is dependent upon a detailed analysis of internal morphology.

Comparison and affinities: The validity of this genus has been questioned by several workers and for differing reasons. Schubert (1920), when erecting the genus, did not designate a type species. Some authors have listed *Textularia cuneiformis* Jones, 1850, as the genotype without actual designation, and in spite of the fact that Schubert deliberately and explicitly excluded this species from the genus. Galloway and Ryniker (1930) designated *Textularia "textulariformis* (Möller)" of Schellwien (1898) (renamed *Palaeotextularia schellwieni* Galloway and Ryniker, 1930) as the type species. This choice was rather unfortunate, however, since Schellwien's description and figure are based on a steinkern and hence lack details of wall structure.

Although Glaessner (1945, pp. 98-99) recognised the differences between the Palaeozoic textulariines and the Textulariidae, insofar as wall structure is concerned, he questioned "the existence of the hypothetical ancestral genus '*Palaeotextularia*,'" and the proof of same. In recent years, the results of both British and Russian research, not to mention the fundamental work of Galloway and others in the United States, have supplied ample evidence of the existence of *Palaeotextularia* in the Carboniferous.

The distinction and relationship of *Palaeotextularia* and *Textularia* have been discussed already.

Preservation and matrix: The presence of a layer of adventitious material, complete or impersistent, distinct or embedded in the outer surface of the granular calcareous layer, has been noted by several workers. Thus, Galloway and Ryniker (1930) recorded foreign particles on the outer surface of *Palaeotextularia grahamensis* (Cushman and Waters), and Reitlinger (1950) has figured examples from the Russian Carboniferous, in which the foreign material includes small foraminifera.

It should be noted, however, that this evidence of an agglutinating habit is found only in specimens possessing a relatively thick test wall. In other instances, it is doubtful if the forms possessing foreign material in the wall can be referred to the Palaeotextulariidae in all cases.

As yet, no conclusive evidence of agglutination has been noted in material from the British Lower Carboniferous. Some granules of silica have been noted in palaeotextulariids from Scottish localities, but the form of the silica and the petrology of the host sediment suggest that these have arisen as a result of secondary silicification. British palaeotextulariids frequently exhibit distortion and collapse as a result of fossilisation. The suggestion by Brady (1876) that some possessed a labyrinthic interior arises from his misinterpretation of the morphology of collapsed specimens that had undergone secondary mineralisation.

Horizon and facies: Palaeotextularia appears in the lower and middle Tournaisian as a relatively rare but widely distributed form, becoming increasingly abundant in the upper Tournaisian and lower Visean. It extends upward into the Upper Carboniferous with diminishing frequency, and gradually becomes extinct in the Lower Permian. It has been recorded from the Carboniferous and Permian of Asia, Europe, and America, and is largely confined to the limestone and calcareous shale facies. Records of *Palaeotextularia* occurring in the Ordovician and Silurian are incorrect, and are a result of the tendency, on the part of some authors, to include all Palaeozoic textulariids in the Palaeotextulariidae.

Revision of the Upper Palaeozoic records of *Palaeotextularia* is summarised:

UPPER PALAEOZOIC SPECIES REFERABLE TO *Palaeotextularia:*

Palaeotextularia davisella Cummings, **new species**

Textularia gibbosa d'Orbigny. – BRADY, 1876, Monogr. Carb. and Permian foram., p. 131, pl. 10, fig. 26.
Textularia gibbosa d'Orbigny of other authors (*non* d'Orbigny).

Description: Test free, small, strongly tapering throughout, with circular to squarish cross section; consisting of six pairs of alternating chambers, gradually and regularly increasing in size as added, except in adult portion where chambers become relatively larger and inflated; sutures rather faint in initial portion, becoming distinct and depressed in later part; peripheral margin lobulate and with rounded edges; wall thick, with main granular calcareous element and thin, impersistent inner "fibrous" buttresses in some of the later chambers; aperture a high semicircular opening at base of domed face of final chamber, on inner margin.

Dimensions: Length of holotype 1.25 mm.; maximum breadth 0.8 mm.

Holotype: Slide P.35423 in the Brady Collection of Carboniferous and Permian Foraminifera, British Museum (Natural History), from the Main Limestone, Lower Limestone Group, Lower Carboniferous, of Brockley, Lanarkshire, Scotland.

Comparison and affinities: Examination of the figured material of *Textularia "gibbosa* d'Orbigny" of Brady (1876) shows that this form is not a species of *Textularia* and cannot be grouped within d'Orbigny's species. Sections of similar specimens from the type locality of Brockley reveal the compound wall structure and single apertural condition typical of *Palaeotextularia.*

This species is distinguished from *Palaeotextularia angulata,* n. sp. by the larger size, the greater inflation of the final chambers, the differing form of the aperture, and the circular cross section.

Horizon and facies: Palaeotextularia davisella is confined to the Lower Limestone Group in Scottish areas, being a common and widespread form in both limestones and calcareous shales. It occurs at equivalent horizons in northern England.

Palaeotextularia angulata Cummings, **new species**
Plate 1, figure 4

Description: Test small, free, stout, strongly tapering in all but the adult portion, with rectangular cross section; consisting of about five pairs of chambers, gradually and regularly increasing in size as added, with width in excess of height; sutures rather faint, very shallow and broad, with the zig-zag suture lying on the wider lateral surfaces; peripheral margin with little or no lobulation and squarish edges; wall thick, with main granular calcareous element and thin, impersistent inner "fibrous" buttresses in some of the later chambers; aperture a low lunate opening at the base of the domed final chamber, with some indications of irregularity leading to an incipient cribrate condition.

Dimensions: Length of holotype 0.6 mm.; maximum breadth 0.49 mm.

Holotype: Slide 11316 of the Reserve and Study Collection, H.M. Geological Survey, Edinburgh Office, from the Lower Linn Limestone, Upper Limestone Group, Namurian, of Caaf Water, near Dalry, Ayrshire, Scotland.

Paratype: Slide 11318 (thin section) in the same collection, from the same horizon and locality.

Comparison and affinities: This form differs from *Palaeotextularia davisella*, n. sp., in the absence of inflation in the final portion and the angularity of the test.

Preservation and matrix: A great deal of the type material has undergone secondary alteration by recrystallisation and iron enrichment. In some cases, partial dolomitisation of the host sediment has led to the formation of small blebs of dolomite within the walls of the test. These could be misinterpreted as quartz grains arising from an agglutinate mode of growth.

Horizon and facies: The records of *Textularia "gibbosa"* Brady (1876) (*non* d'Orbigny) in the Upper Limestone Group of the Scottish Namurian are based on the occurrence of this form. *Palaeotextularia angulata* is a comparatively rare but widespread form in the Upper Limestone Group, particularly of Ayrshire and Lanarkshire.

In addition, the following forms of *Palaeotextularia* have been described previously:

Palaeotextularia asper Cooper, 1947 (*recte aspera, fide* Thalmann, 1949);
Palaeotextularia bella Lipina, 1948;
Palaeotextularia breviseptata Lipina, 1948;
Palaeotextularia consobrina Lipina, 1948;
Palaeotextularia consobrina var. *intermedia* Lipina, 1948;
Palaeotextularia diversa Chernysheva, 1948;
Palaeotextularia dobroljubovae Rauser-Chernoussova and Reitlinger, 1936;
Palaeotextularia "gibbosa (d'Orbigny)" var. *minima* Lipina, 1948;
Palaeotextularia lata Chernysheva, 1940;
Palaeotextularia longiseptata Lipina, 1948;
Palaeotextularia longiseptata var. *crassa* Lipina, 1948;
Palaeotextularia longiseptata var. *fallax* Lipina, 1948;
Palaeotextularia longiseptata var. *magna* Lipina, 1948;
Palaeotextularia oblonga Rauser-Chernoussova and Reitlinger, 1936;
Palaeotextularia sp. of Harlton (1933).

Revision of earlier records by previous workers has led to the inclusion of further species in the genus:

Palaeotextularia schellwieni Galloway and Ryniker, 1930, based on *Textularia "textulariformis* (Möller)" of Schellwien (1898) (*non Cribrostomum textulariforme* Möller, 1879), and designated the type species by Galloway and Ryniker (1930);
Palaeotextularia grahamensis (Cushman and Waters) of Galloway and Ryniker (1930), transferred from *Textularia grahamensis* Cushman and Waters, 1927.

The present revision of earlier records leads to the inclusion of further species within the genus:

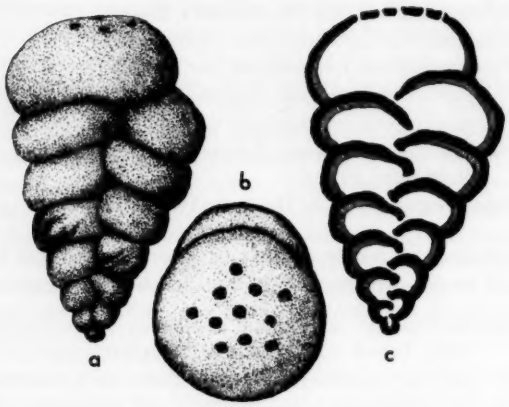
**Textularia angusta* Reitlinger, 1950;
Textularia angusta var. *decurta* Reitlinger, 1950;
**Textularia angusta* var. *elongata* Reitlinger, 1950;
Textularia angusta var. *maxima* Reitlinger, 1950;
Textularia bruta Reitlinger, 1950;
Textularia eofragilis Reitlinger, 1950;
Textularia fragilis Reitlinger, 1950;
Textularia gibbosaeformis Reitlinger, 1950;
Textularia grandis Reitlinger, 1950;
Textularia longissima Reitlinger, 1950;
Textularia minutissima Reitlinger, 1950;
Textularia paracommunis Reitlinger, 1950;
**Textularia ponderosa* Reitlinger, 1950;
Textularia primitiva Reitlinger, 1950;
Textularia sumatrensis Lange, 1925;
Textularia thorax Lange, 1925;
Textularia vulgaris Reitlinger, 1950;
Bigenerina perrodata Lange, 1925.

The specific and varietal names marked with an asterisk (*) have been indicated as preoccupied, by Thalmann (1952).

Genus **Cribrostomum** Möller, 1879
Text-figure 10a-c

Textularia Defrance. – Ehrenberg (1843), Eichwald (1860), Brady (1876), and other authors (in part).
Grammostomum Ehrenberg. – Ehrenberg (1843) (in part).

Type species: Cribrostomum textulariforme Möller, 1879, designated by Cushman (1928*a*).



TEXT-FIGURE 10

Cribrostomum sp., diagrams showing typical appearance: a, lateral view of complete specimen illustrating chamber deflation in neanic portion; b, apertural view of complete specimen; c, longitudinal axial section.

Description: Test free, stout, straight or slightly curved, tapering or with a tapering initial portion followed by a cylindrical adult part; consisting of a spherical proloculum succeeded by appressed, compressed, or inflated chambers biserially arranged and forming the greater part of the test, and with a final inflated chamber usually lying obliquely to the line of growth and often extending over part or over the whole of the terminal surface of the two preceding chambers; sutures faintly to strongly depressed and often broad; internally, septa vary in shape, curvature, and thickness and sometimes exhibit shortening by resorption in neanic stages; periphery usually lobulate, with rounded or squarish cross section and well marked zig-zag suture; surface rarely smooth and frequently granular; wall consists of a main granular calcareous element, together with an incomplete inner "fibrous" layer, often of variable thickness and in the form of a lining or buttress on the inner surface of the chamber wall, and rarely a third thin external cover of adventitious material embedded in the main element; aperture in the early portion a low circular or lunate slit at the base of the final chamber on the inner margin, but in the last one or two adult chambers cribrate, consisting of numerous circular perforations spread over the domed terminal face of the chamber; a transitional incipient cribrate phase between these two apertural conditions may or may not be present.

In thin section, representatives of this genus may be identified, in axial section only, by the characteristic compound wall structure and the pattern of chamber arrangement, terminating in a cribrostomoid A or B condition (see text-figure 10a-c).

The distinction of the adult *Cribrostomum* from the juvenile forms of the more advanced genera is dependent upon a detailed analysis of internal morphology.

Comparison and affinities: The status and validity of *Cribrostomum* and its relationship to *Climacammina* have been discussed by many authors, notably Möller (1879), Cushman (1928*a*), Plummer (1945), and Reitlinger (1950). Confusion has arisen over the distinction between ontogenic stage on the one hand, and morphogenetic or phylogenetic stage on the other. The reason for the recognition of *Cribrostomum* as a distinct genus in this paper lies in the analyses of assemblages from the British Visean. These show that the condition represented by *Cribrostomum* is present as the adult stage of palaeotextulariids within this stratigraphic interval.

The genus may be distinguished from *Climacammina* by the absence of a distinct uniserial stage of two or more chambers, and from *Palaeotextularia* by the presence of a cribrate aperture and an asymmetrically arranged final chamber.

Preservation and matrix: Often the chambers of *Cribrostomum* are deflated during fossilisation, particularly in the nepionic stage, where resorption of the septa is a common phenomenon (see text-figure 10a).

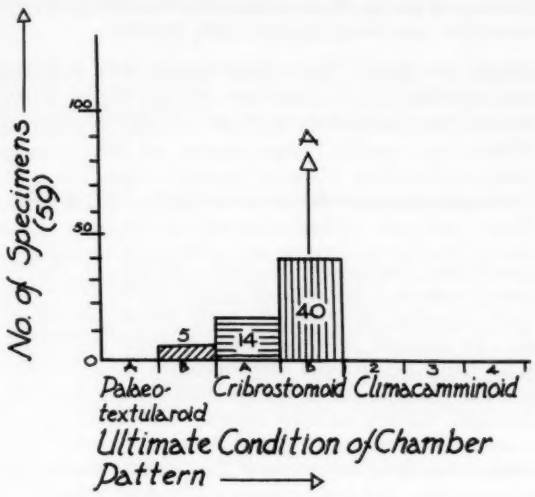
Horizon and facies: Cushman (1928*a*) lists *Cribrostomum* as a Carboniferous and Permian form, but it would seem that it is rarely, if ever, found outside the Carboniferous. The Permian records are based on isolated examples of juvenile forms of *Climacammina*, and have been described without reference to population analysis or detailed morphology. Appearing toward the top of the Tournaisian, the genus rapidly becomes a dominant member of British Visean foraminiferal assemblages, and continues, with diminishing frequency, into the Namurian. It is present in the Pennsylvanian of the United States, and has been recorded as a relatively rare form from the Middle Carboniferous of the U.S.S.R.

Revision of the Upper Palaeozoic records of *Cribrostomum* is summarised:

A. UPPER PALAEOZOIC SPECIES REFERABLE TO *Cribrostomum:*

Cribrostomum scoticum Cummings, **new species**
Plate 1, figure 5; text-figure 11

Description: Test relatively large, elongate, tapering, with rectangular cross section in early part, becoming inflated and with a circular cross section in adult stages; consisting of some seven pairs of biserially arranged chambers, the last one of which often exhibits an asymmetry of alignment and a tendency to lateral extension, all gradually increasing in size as added and laterally compressed, together with one final inflated chamber covering the terminal faces of the two preceding chambers completely and lying in the uniserial position; externally, the change of growth is shown by the commencement of marked inflation in the penultimate biserial chamber; sutures depressed and distinct throughout, but especially well marked in



TEXT-FIGURE 11

Expression of the adult condition of *Cribrostomum scoticum* by population analysis.

adult portion; peripheral margin faintly to sharply lobulate; external surface rough and pitted; wall relatively thick, with granular calcareous main element (often altered to secondary iron carbonates), and incomplete inner "fibrous" layer (often absent); aperture in the early part of the test a low lunate slit, but in the adult portion cribrate, consisting of some eight to twelve circular perforations arranged more or less regularly in the central region of the inflated terminal face of the last chamber; internally, the change of growth is shown by septal retreat and alteration of apertural form.

Dimensions: Length of holotype 1.54 mm.; maximum breadth 0.66 mm.; length of biserial portion 1.15 mm.

Holotype: Slide 11317 in the Reserve and Study Collection, H.M. Geological Survey, Edinburgh Office, from the shales overlying the Charlestown Main Limestone, Lower Limestone Group, Lower Carboniferous, of Wilkieston Quarry, near Cupar, Fife, Scotland.

Comparison and affinities: In the adult stage, this species differs from *Cribrostomum wilkiestoni* Cummings, n. sp., in the arrangement of the two final chambers and in the apertural form. The adult form of *Cribrostomum wilkiestoni* and the neanic stage of *Cribrostomum scoticum* are distinguished by the inflated final chamber of the former and the distinct apertural arrangement of the latter.

Preservation and matrix: In keeping with all microfauna from Wilkieston Quarry, the type material exhibits an unusual state of preservation. The original granular calcareous material of the wall has been replaced by limonite and/or siderite. This change appears to be a result of the development of the present ochreous condition of the host sediment. This alteration has also led to the obliteration of the inner "fibrous" layer in many instances, and a further result is that the tests appear opaque in transmitted light (see plate 1, figure 14).

Population analysis: In order to distinguish the adult condition of individual morphologic species, an analysis of population has been carried out on type material wherever this was possible. Assemblages from the type locality have been examined, and an analysis of the ontogenic stages of the more highly developed specimens has revealed the detailed pattern of their growth. Less well developed specimens in the assemblage have been compared with the stages of this pattern, and, where marked similarity occurred in all biocharacters, they have been identified as juvenile or embryonic forms. If no such similarity exists, the forms are not regarded as conspecific.

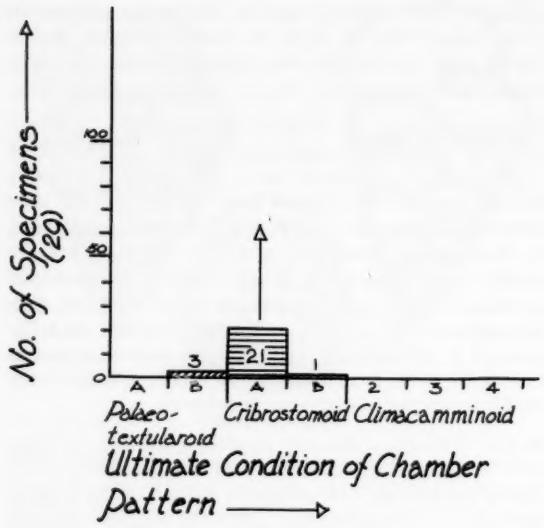
By such methods, it becomes possible to identify the ontogenic stage of individual specimens and the adult condition of the species. The ontogenic pattern of the population may be expessed, in the case of the palaeotextulariids, in terms of the frequency of types of chamber form and pattern, the dominant biocharacter.

Analysis of a population of fifty-nine specimens from one layer of shale in the type locality of Wilkieston Quarry shows a dominant cribrostomoid B stage as the adult condition of *Cribrostomum scoticum* (see text-figure 11).

Horizon and facies: This form occurs in the limestone and calcareous shale facies of the British Lower Carbiniferous in all areas. Nowhere, however, is it abundant, and it would appear to be confined to the upper Visean. In Scotland, it has been recorded from the Hurlet Limestone horizon in the west and the No. 2 Limestone in the east of the Midland Valley, and again toward the top of the Calciferous Sandstone Series in Dumfriesshire. Equivalent horizons in England contain small numbers of *Cribrostomum scoticum*.

Cribrostomum wilkiestoni Cummings, **new species**
Plate 1, figure 6; text-figure 12

Description: Test relatively small, straight or slightly curved, rather squarish in cross section; consisting of five pairs of biserial chambers gradually increasing in size as added, and one final inflated chamber lying oblique to the axis of the test and covering some two-thirds of the terminal area of the two preceding chambers; sutures faintly depressed and narrow in early part, giving a smooth outline, which is broken by inflation and by distinct, depressed, rather broad sutures of the later part; rounded to almost square in cross section, with an increase of lobulation of peripheral margin toward apertural region; surface rough and pitted; wall relatively thick, consisting of a main granular calcareous element with an incomplete inner "fibrous" buttressing of chambers in later part of test; aperture cribrate, on inflated terminal face of last chamber, composed of a central small circular opening



TEXT-FIGURE 12

Expression of the adult condition of *Cribrostomum wilkiestoni* by population analysis.

with a faint neck, surrounded by a circlet of smaller ellipsoidal openings.

Dimensions: Length of holotype 1.05 mm.; maximum breadth 0.6 mm.; length of biserial portion 0.66 mm.

Holotype: Slide 11323 in the Reserve and Study Collection, H.M. Geological Survey, Edinburgh Office, from the shales overlying the Charlestown Main Limestone, Lower Limestone Group, Lower Carboniferous, of Wilkieston Quarry, Fifeshire, Scotland.

Paratype: Slide 11324 (thin section) in the same collection, from the same horizon and locality.

Comparison and affinities: This form is distinguished from *Cribrostomum scoticum,* in adult specimens, by the obliquity of the final chamber and the apertural pattern. On similar grounds, the adult form may also be distinguished from the neanic stage of *Cribrostomum scoticum,* which possesses a cribrostomoid A chamber pattern. *Cribrostomum wilkiestoni* differs from *Cribrostomum textulariforme* Möller in having fewer chambers, a distinct apertural arrangement, and in being smaller.

Preservation and matrix: Although the distinctive alteration mentioned above in the case of *Cribrostomum scoticum* occurs in the type material of this species also, it differs in the frequent retention of the "fibrous" layer. The dark black or brown colour of specimens from the type locality is due to the abundant and extremely small particles of limonite.

Population analysis: Detailed morphological study and population analysis show that this form must be considered as a distinct species, even though it is represented by only twenty-five specimens from the type locality.

Horizon and facies: This extremely rare form is known only from the No. 2 Limestone horizon of the Lower Carboniferous in the eastern part of the Scottish Midland Valley.

Cribrostomum ponielum Cummings, **new species**
Plate 1, figure 7

Description: Test relatively large, straight or slightly curved, squarish to rectangular in cross section, slowly and evenly tapering; consisting of some thirteen chambers, biserially arranged after the initial spherical proloculum, each slightly inflated and subcuboidal in form, followed by a final chamber that is slightly inflated, asymmetrically positioned, circular in cross section, with width greatly in excess of height and with a flattened terminal face, which covers some two-thirds of the terminal area of the two preceding chambers; sutures moderately broad, only slightly depressed; peripheral margin very faintly lobulate; surface rough and pitted; wall relatively thick, with granular calcareous main element and incomplete inner "fibrous" buttresses; aperture in adult form irregularly cribrate, on flat terminal face of final chamber, in earlier portion in the form of a low lunate slit.

Dimensions: Length of holotype 1.54 mm.; maximum breadth 0.83 mm.; length of biserial portion 1.05 mm.

Holotype: Slide P.3603 in the Protozoa Collection, Department of Geology, University of Glasgow, from the shales overlying the Main Limestone, Lower Limestone Group, Lower Carboniferous, of Brockley, near Lesmahagow, Lanarkshire, Scotland.

Comparison and affinities: This species is distinguished from *Cribrostomum scoticum* by the marked angularity of the test and the absence of a uniserially positioned final chamber. In some respects *Cribrostomum ponielum* is similar to *Cribrostomum "eximium* (Eichwald)" of Möller (*non* Eichwald), but differs in the greater angularity of the test, the smaller size, and the absence of distinct lobulation and inflation.

Preservation and matrix: It is a noticeable feature that, although specimens of this form have been obtained from bands of differing lithology at one locality, Brockley, there is no fundamental change in the structure of the test wall. Specimens taken from a sandy calcareous shale have a wall structure identical with those from non-sandy calcareous shale bands, although, in the case of the former, there has been a slight iron enrichment which is also noticeable in the host sediment.

Horizon and facies: This species has been recorded from a few localities in the lower part of the Lower Limestone Group, Lower Carboniferous, of Lanarkshire and Ayrshire; a comparatively rare form, it is confined to the calcareous shale facies, both sandy and non-sandy.

Cribrostomum inflatum Cummings, **new species**
Plate 1, figure 8

Description: Test free, small, stout, straight or slightly curved, with a circular cross section in the early part but becoming squarish in adult portion, evenly and gradually tapering, with no distinct growth change; consisting of about ten slightly inflated biserially arranged chambers, whose height is more or less equal to their width, and a single relatively larger, inflated final chamber, slightly asymmetrical in position; sutures rather broad and shallow, moderately depressed; peripheral margin faintly lobulate; surface rough and pitted; wall composed of a granular calcareous main element and incomplete inner "fibrous" buttresses in some of the latter chambers; aperture in early portion a low lunate slit, but in adult irregularly cribrate, in a central position on the domed terminal face of final chamber.

Dimensions: Length of holotype 0.88 mm.; maximum breadth 0.6 mm.

Holotype: Slide 11313 in the Reserve and Study Collection, H.M. Geological Survey, Edinburgh Office, from the shales overlying the Charlestown Main Limestone, Lower Limestone Group, Lower Carboniferous, of Wilkieston Quarry, near Cupar, Fife, Scotland.

Comparison and affinities: This form is distinguished from the ephebic stage of *Cribrostomum "eximium* (Eichwald)" of Möller (*non* Eichwald) by the absence of a strongly asymmetrical final chamber with marked inflation. It may be confused with the neanic stage of Möller's form, but the latter exhibits a marked change in growth pattern which is not present in *Cribrostomum inflatum.*

Horizon and facies: Cribrostomum inflatum is a rare form, known only from the No. 2 Limestone and its equivalents in the eastern part of the Midland Valley of Scotland. The records of *Textularia "eximia* Eichwald" of Brady (1876) (*non* Eichwald) occurring in such Scottish formations are based on the presence of this species.

Cribrostomum linnum Cummings, **new species**
Plate 1, figure 9

Description: Test free, small, straight or slightly curved, smoothly and evenly tapering except in earliest portion, rectangular to subrounded in cross section; consisting of some twelve overlapping biserially arranged chambers, whose respective heights are almost equal to their widths and in which the last five or six show a much greater inflation and are relatively larger than the earlier ones, together with a final chamber that maintains the textularioid form of the test and extends only slightly over the terminal face of the first chamber of the preceding pair; the marked change of growth is also shown by the indistinct sutures of the early part rapidly giving place to the relatively broad, moderately depressed, distinct sutures of the adult portion; peripheral margin smooth in early part but lobulate in adult portion; surface smooth and slightly granular; wall rather thick, consisting of a granular calcareous main element, with incomplete inner "fibrous" buttresses in later chambers; aperture at base of last-formed chamber on median line, a low lunate opening in early portion, but in adult an irregularly cribrate opening advancing into centre of terminal face of final chamber.

Dimensions: Length of holotype 0.83 mm.; maximum breadth 0.55 mm.

Holotype: Slide 11314 in the Reserve and Study Collection, H.M. Geological Survey, Edinburgh Office, from the Lower Linn Limestone, Upper Limestone Group, Namurian, of Caaf Water, near Dalry, Ayrshire, Scotland.

Comparison and affinities: In many ways, *Cribrostomum linnum* is an anomalous form. It possesses a palaeotextularioid B condition of chamber arrangement, and the final chambers show little or no asymmetry of alignment, a feature that is present to a varying degree in most cribrostomids. Nevertheless, the incipient cribrate aperture illustrates the close affinity to *Cribrostomum.* Although this species cannot be regarded as the phylogenetic link between *Palaeotextularia* and *Cribrostomum,* in view of its stratigraphic position, it might be regarded as the morphogenetic expression of such a link form.

Horizon and facies: This species is confined to the limestones of the Upper Limestone Group in the western part of the Midland Valley of Scotland.

Cribrostomum oveyi Cummings, **new species**

Textularia eximia Eichwald. – Brady, 1876, Monogr. Carb. and Permian foram., pp. 132-133, pl. 10, figs. 27-29.
Textularia eximia Eichwald of other authors (part).

Description: Test free, moderately large, rarely straight but usually slightly curved, gradually and evenly tapering throughout, with subrectangular cross section; consisting of about sixteen inflated biserially arranged chambers, whose respective widths exceed their heights, together with two final chambers showing a marked inflation and with the last in an asymmetrical position and extending over half the terminal face of the penultimate chamber; sutures rather broad and moderately depressed, becoming strongly depressed in final portion; peripheral margin lobulate throughout; wall rather thick, consisting of a granular calcareous main element, with incomplete inner "fibrous" buttresses in later chambers; aperture a low lunate slit in early portion, but irregularly cribrate in adult, on terminal face of last-formed chamber.

Dimensions: Length of holotype 1.6 mm.; maximum breadth 0.63 mm.

Holotype: Ex slide P.35424 in the Brady Collection of Carboniferous and Permian Foraminifera, British Museum

(Natural History), from the Yoredale Series, Skellygate Limestone, Lower Carboniferous, of the Skellygate Old Quarries, Ridsdale, Northumberland, England; figured by Brady (1876, pl. 10, fig. 27a-b).

Comparison and affinities: Examination of the type material of *Textularia "eximia* Eichwald" of Brady (1876) (*non* Eichwald) shows that this form cannot be referred to *Textularia*. The type material is contained in two slides, P.35422 and P.35424, in the Brady Collection at the B.M.N.H. Nearly all specimens, including those figured by Brady (pl. 10, figs. 27-29), are ferruginous steinkerns and have undergone severe distortion in some cases. The asymmetry of the final chamber and the cribrate nature of the aperture indicate that this form must be referred to *Cribrostomum*.

This form is considered distinct from *Cribrostomum "eximium* (Eichwald)" of Möller (*non* Eichwald) and from *Cribrostomum bradyi* Möller, although Möller (1879) included *Textularia "eximia* Eichwald" of Brady (1876) within the latter, and regarded Brady's species as the young form.

Horizon and facies: This species is common in the upper Visean of northern England and the Lower Limestone Group of the Scottish Lower Carboniferous. It is confined to the limestone and calcareous shale facies.

In addition, the following species of *Cribrostomum* have been described previously:

Cribrostomum "eximium (Eichwald)" of Möller (1879) (*non* Eichwald);
Cribrostomum "eximium (Eichwald)" var. *eximiformis* Lipina, 1948;
Cribrostomum "eximium (Eichwald)" var. *paraeximia* Lipina, 1948;
Cribrostomum "eximium (Eichwald)" var. *regularis* Lipina, 1948;
Cribrostomum posteximium Reitlinger, 1950;
Cribrostomum recurrens Lipina, 1948;
Cribrostomum stalinogorski Lipina, 1948;
Cribrostomum textulariforme Möller, 1879.

B. Upper Palaeozoic species that may be referable to *Cribrostomum:*

Whilst it is possible in some instances to identify all the biocharacters of the species described by Möller (1879), there are several cases in which the idealized figures and the grouping of unrelated forms renders this impossible. The following forms may prove referable to *Cribrostomum* on further study:

Cribrostomum bradyi Möller, 1879;
Cribrostomum commune Möller, 1879;
Cribrostomum "patulum (Brady)" of Möller (1879).

Although Cushman and Waters (1928*a*) noted the following species as juvenile forms, no descriptions of the adult condition of these species were given. Further study and population analysis may show them to be referable to *Cribrostomum:*

Cribrostomum attenuata Harlton, 1928;
Cribrostomum jeffersonensis Harlton, 1927.

C. Upper Palaeozoic species not referable to *Cribrostomum,* whose correct generic placing is known:

The revision of records by previous workers may be listed:

Cribrostomum cushmani Harlton, 1928, listed as *Climacammina cushmani* (Harlton) by Cushman and Waters (1928*a*) after population analysis;
Cribrostomum lucilleae Harlton, 1927, listed as *Climacammina lucilleae* (Harlton) by Warthin (1930).

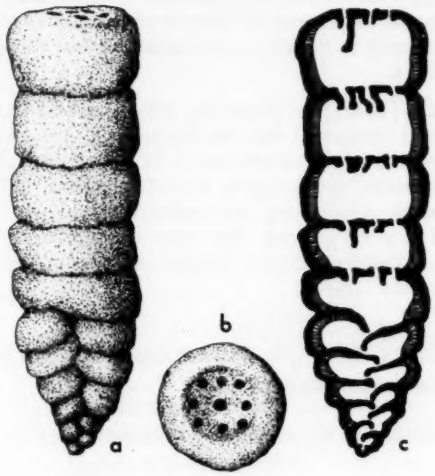
The present revision leads to further amendments. All the following species must be placed in *Climacammina,* in view of the multichambered character of their uniserial portion:

Cribrostomum brevis Reitlinger, 1950;
Cribrostomum elegans Möller, 1879 *(non Bigenerina "elegans* (Möller)" of Schellwien, 1898);
Cribrostomum gracile Möller, 1879;
Cribrostomum infundibulum Lee and Chen, 1930;
Cribrostomum laxum Lee and Chen, 1930;
Cribrostomum longissimoides Lee and Chen, 1930;
Cribrostomum nelumboforme Lee and Chen, 1930;
Cribrostomum pyriforme Möller, 1879;
Cribrostomum spathulatum Lee and Chen, 1930;
Cribrostomum stiloforme Lee and Chen, 1930.

D. Upper Palaeozoic species not referable to *Cribrostomum,* but which require further study before correct generic placing can be effected:

The following species are based on imperfect non-axial thin sections in limestone, and, whilst not referable to *Cribrostomum* in view of the multichambered character of the uniserial portion, require further study to ascertain the pattern of apertural condition. The results of this should show whether they are to be included in *Climacammina* or *Cribrogenerina*:

Cribrostomum "eximium (Eichwald)" of Lee, Chen and Chu (1930) (*non* Eichwald, Möller, etc.);
Cribrostomum maximum Lee and Chen, 1930;
Cribrostomum moelleri Lee and Chen, 1930.



TEXT-FIGURE 13

Climacammina sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen; c, longitudinal axial section.

Genus **Climacammina** Brady, 1873
Text-figure 13a-c

Climacammina Brady, 1873, and Brady (1876).
Bigenerina d'Orbigny. – Brady (1876, 1884), Schellwien (1898), and other authors (in part).
Cribrostomum Möller, 1879, and other authors (in part).
Moellerina Eimer and Fickert, 1899 (*non Moellerina* Ulrich, 1886; *non Möllerina* Schellwien, 1898).
Textularia Defrance. – Brady (1871) and other authors (in part).

Type species: Textularia antiqua Brady, 1871, in Young and Armstrong (1871).

Description: Test free, elongate, tapering in early portion, usually subcylindrical to slowly tapering in adult part, often of irregular contour, straight or slightly curved; consisting of numerous distinct chambers after a spherical proloculum, overlapping and biserially arranged in nepionic and early neanic parts; in some forms the later neanic portion of the test may have a cribrostomoid chamber arrangement over two or three chambers, but this is not always present; the adult portion of the test consists of two or more short, broad, slightly inflated chambers arranged in a straight or slightly curved uniserial pattern; sutures distinct, faintly to strongly depressed, often broad; internally, septa show variation in shape, curvature and thickness, and are frequently foreshortened, especially in the adult portion; peripheral margin lobulate, strongly so in uniserial portion; cross section circular to squarish; surface often rough and pitted, giving an "arenaceous appearance"; wall relatively thick, composed of a main granular calcareous element, showing dark in transmitted light, and an incomplete inner clear "fibrous" layer in the form of linings or buttresses, together with a further thin, impersistent layer of agglutinated adventitious material on or embedded in the exterior surface and occurring as a complete veneer, in patches, or often absent; aperture in the early portion a low, lunate opening at the base of the terminal face on the inner margin, later spreading onto the terminal face and becoming irregularly cribrate, although this intermediate phase may be absent; in the adult part the aperture is regularly or irregularly cribrate, consisting of round or ellipsoidal holes on the terminal face of the uniserial chambers; often the assumption of the adult apertural condition is accompanied internally by septal shortening and/or the formation of vestibular siphons and septal pillars.

In thin section, representatives of this genus may be identified, in axial section only, by the characteristic compound wall structure and the sequence of chamber and apertural patterns (see text-figure 13a-c). The distinction of young forms of *Climacammina* from the adult stages of simpler genera is dependent upon detailed morphologic analysis.

Ontogeny: The ontogeny of *Climacammina* has been described in detail by Cushman and Waters (1928*a*), but the pattern of development outlined therein is not constant for the genus. Later work, including present results, shows that the spherical proloculum is succeeded by a biserial palaeotextularioid stage of varying size, in which the apertures are in the form of simple lunate slits. In Lower Carboniferous species, this is often succeeded by a cribrostomoid stage, in which the aperture becomes irregularly cribrate and advances onto the upper surface of the final chamber. This stage is omitted, however, in some Lower Carboniferous forms, in many of the Middle Carboniferous species of the U.S.S.R. described by Reitlinger (1950), and in the majority of Upper Carboniferous and Permian forms. In such instances, the palaeotextularioid stage is followed either immediately by the climacamminoid stage, or, more rarely, by an extremely short interval of one or two chambers that have a single simple circular aperture in a central position on the terminal face. The significance of this condition is not understood, but it may indicate the polyphyletic nature of the genus and the local dominance of the bioseries of apertural form. Whatever the intermediate nature of the test, the adult part is represented by the climacamminoid stage, with two or more uniserial chambers possessing cribrate apertures of varying pattern. In the adult condition, the number of chambers in the climacamminoid pattern shows a progressive increment at successively higher stratigraphic horizons, as has been indicated already by Reitlinger (1950).

Comparison and affinities: The distinction between *Climacammina* Brady, 1873, and *Cribrostomum* Möller, 1879, is rendered difficult because of their close phylogenetic situations. Cushman and Waters (1928*a*) regarded the

shape of the pores in the cribrate condition as significant, suggesting that the circular character of the pores in *Cribrostomum* was not developed to the same degree in *Climacammina*. Since most of Möller's figures are idealized, this morphologic difference can be of little importance. Again, Plummer (1945) suggested that the degree of external symmetry was a reliable criterion in distinguishing the two genera, but evidence of distortion and secondary alteration shows that such a view is incorrect or misleading.

The present description of *Climacammina* is based on a re-examination of the type material, and that of *Cribrostomum* given above is based on the original description and analysis of *Cribrostomum textulariforme* Möller, 1879. These show that the fundamental distinction between the two genera in their adult conditions lies in the length of the uniserial portion. *Climacammina* has at least two uniserial chambers, whilst *Cribrostomum* has either an asymmetrically arranged final chamber of a biserial series, or, at most, one inflated final chamber arranged in a uniserial manner. Other features, such as the absence of a cribrostomoid stage in many species of *Climacammina*, enhance the fundamental distinction.

The cribrate nature of the aperture distinguishes *Climacammina* from both *Deckerella* Cushman and Waters, 1928, and *Palaeobigenerina* Galloway, 1933.

Preservation and matrix: Specimens of *Climacammina* are rarely preserved without distortion and crushing during fossilisation. This may lead to misinterpretation of morphology. Thus, the variation in form of *Climacammina antiqua* described by Brady (1876, p. 69) is not original but is due to distortion. As Cushman and Waters (1928*a*) indicated, the relatively thinner wall of the uniserial portion facilitates crushing, and it might be added that the shortening of the septa prevalent in this part of the test would enhance this facility.

Galloway (1933) describes the test wall of this genus as "partially a network of cryptocrystalline silica," but the present study has provided no evidence to show that this is a primary condition. Indeed, the frequency of secondary silica, amorphous or crystalline, in the wall structure of specimens from the Lower Limestone Group of Ayrshire, Scotland, is a direct reflection of the occurrence of secondary silicification at certain localities in the area.

Horizon and facies: Climacammina occurs throughout the greater part of the Carboniferous and Permian, being absent from the Tournaisian and the Upper Permian, and has a world-wide distribution. In the British Lower Carboniferous, it appears for the first time in the Visean, and continues with increasing variety and abundance until it forms a dominant unit in upper Visean foraminiferal assemblages. It is known also from the British Namurian.

Reitlinger (1950) states that it is a rare form in the Lower Carboniferous of the U.S.S.R., but common in the Middle and Upper Carboniferous. It has been recorded from many horizons in the American Pennsylvanian, and is particularly common in the Permo-Carboniferous and Permian of the Orient.

Warthin (1930), in describing *Climacammina lucilleae* (Harlton), suggested that the thickness of the wall was directly related to environment. In the British Lower Carboniferous, the variation in wall thickness bears no relationship to changing environments, but seems indicative of phyletic pattern. This view is supported by the work of Reitlinger in the Middle and Upper Carboniferous of the U.S.S.R.

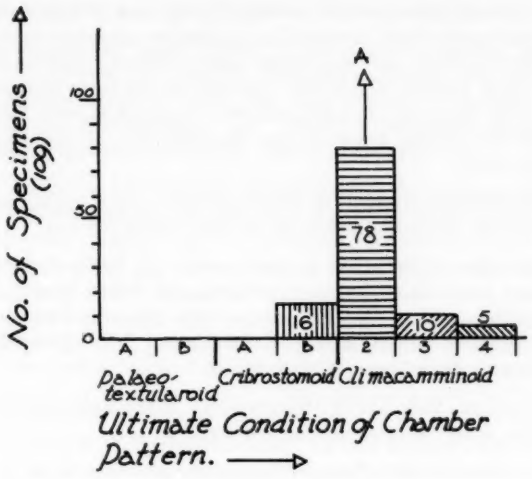
Revision of the Upper Palaeozoic records of *Climacammina* is summarised:

A. Upper Palaeozoic species referable to *Climacammina:*

Climacammina antiqua (Brady)
Plate 1, figures 10-11; text-figure 14

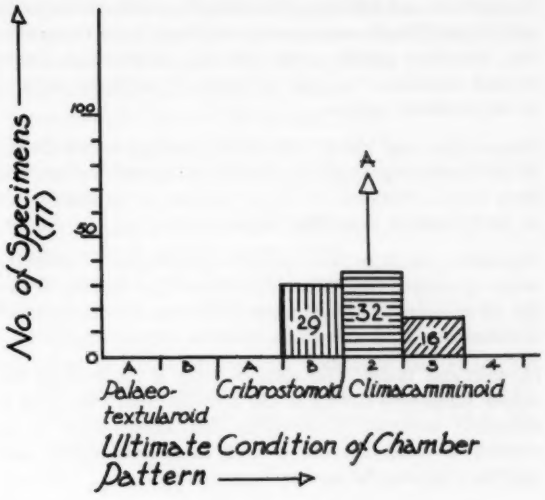
Textularia antiqua Brady, 1871, and others.
Climacammina antiqua (Brady). – Brady (1873, 1876).

Description: Test free, relatively large, straight or slightly curved, with tapering, conical early portion, often separated by a broad and shallow constriction from the later straight cylindrical part; consisting of a distinct spherical proloculum followed by overlapping biserially arranged chambers of early part, with a hemispherical outline, up to fourteen in number, and with width in excess of height; central portion of test consisting of a single inflated, asymmetrical cribrostomoid chamber, extending over some two-thirds of terminal areas of two preceding chambers; later part of test consisting of two to four broad, short uniserial chambers with circular cross section; in early biserial part, sutures are faint and only slightly depressed, with the zig-zag suture often distorted; with increase of chamber inflation towards apertural region, sutures become increasingly distinct and depressed; internally, early chambers separated by relatively thin, overlapping spatulate septa, but in later portion septa are thick, short, and often securiform; peripheral margin tends initially to be smooth and rounded, but becomes much more irregular in adult part; external surface rough and pitted (often having subsidiary creases due to crushing); wall composed of a granular calcareous main element, together with an incomplete, yellowish inner "fibrous" layer occurring as buttresses in the lateral parts of the chambers of both the later biserial portion and the uniserial part; aperture of early chambers a low lunate slit, becoming cribrate about in the fourteenth chamber, and in the climacamminoid uniserial portion consisting of some six to eight small circular openings, often regularly arranged, on the inflated terminal area of the chamber; in the final part the cribrate aperture is associated with ingrowths of the septal and terminal faces (the vestibular siphons).



TEXT-FIGURE 14

Expression of the adult condition of *Climacammina antiqua* by population analysis.



TEXT-FIGURE 15

Expression of the adult condition of *Climacammina supraparva* by population analysis.

Dimensions: Length of lectotype 2.76 mm.; maximum breadth 0.83 mm. Length of figured paratype (fig. 10) 2.97 mm.; maximum breadth 1.1 mm.; length of biserial portion 1.38 mm.

Lectotype: Ex Slide P.35478 in the Brady Collection of Carboniferous and Permian Foraminifera, British Museum (Natural History), from the shales overlying the Main Limestone, Lower Limestone Group, Lower Carboniferous, of Brockley, near Lesmahagow, Lanarkshire, Scotland.

Figured paratypes: Slide P.3600 and Slide P.3601 (figured thin section) in the Protozoa Collection, Department of Geology, University of Glasgow.

Comparison and affinities: This species differs from *Climacammina supraparva* Cummings, n. sp., in its larger size and irregularity of form, and may be distinguished from *Climacammina ferra* on similar grounds.

Preservation and matrix: Recrystallisation of the test wall often leads to the obliteration of the inner "fibrous" layer and its replacement by an irregular mosaic of clear calcite that is indistinguishable, except in grain size, from the calcite of the infilling or steinkern.

Population analysis: Analysis of a population of 109 specimens from the type locality shows that the adult condition is represented by the climacamminoid (2) type of chamber pattern (see text-figure 14).

Horizon and facies: Climacammina antiqua (Brady), as defined herein, has a restricted range within the British Lower Carboniferous, being confined to the Upper Visean. In Scotland, it is characteristic of the uppermost part of the Calciferous Sandstone Series and the lower part of the Lower Limestone Group, occurring in large numbers in the Hurlet Limestone in the west and in the No. 2 Limestone in the east of the Midland Valley. It appears in abundance at equivalent horizons in the English Lower Carboniferous and is particularly common in the shelly limestone facies.

Climacammina supraparva Cummings, **new species**
Plate 1, figure 12; text-figure 15

Description: Test free, small, straight or very slightly curved, laterally compressed, subrounded in cross section, with parallel sides or very gradually tapering in adult portion but sharply tapering in early part; consisting of about twelve very slightly inflated, overlapping, biserially arranged chambers with a rounded margin and flattened sides, followed by some two to three broad, short uniserially arranged chambers with circular cross section; sutures relatively broad and only slightly depressed; peripheral margin faintly lobulate throughout; surface smooth to finely granular; wall thick, composed of a granular calcareous main element and an impersistent inner "fibrous" layer; aperture in early portion a low lunate slit, but in adult part cribrate and situated in the central region of domed apertural face of final chamber.

Dimensions: Length of holotype 1.16 mm.; maximum breadth 0.49 mm.; length of biserial portion 0.77 mm.

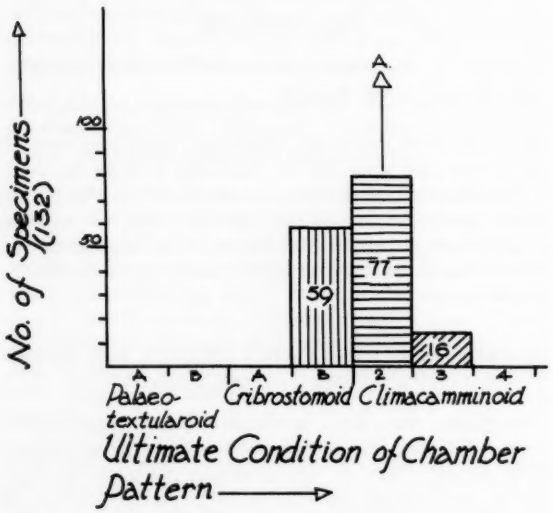
Holotype: Slide 11321 in the Reserve and Study Collection, H.M. Geological Survey, Edinburgh Office, from the Lower Linn Limestone, Upper Limestone Group, Namurian, of Caaf Water, near Dalry, Ayrshire, Scotland.

Comparison and affinities: This form is readily distinguishable from *Climacammina antiqua* (Brady) by its smaller size, smoother profile, more delicate construction, fewer biserial chambers, and the absence of vestibular siphons in the uniserial portion.

Preservation and matrix: In the Upper Limestone Group of the western part of the Scottish Midland Valley, this form occurs frequently in large numbers as internal molds in amorphous or crystalline silica.

Population analysis: Analysis of a population of seventy-seven specimens from a horizon at the type locality shows the adult form to be represented by the climacamminoid (2) condition of chamber arrangement (see text-figure 15).

Horizon and facies: This delicate form is confined to the Upper Limestone Group of the Scottish Namurian, and is especially common in Ayrshire and Lanarkshire. It is present in both limestones and calcareous shales and exhibits a spasmodic mode of occurrence.



TEXT-FIGURE 16

Expression of the adult condition of *Climacammina ferra* by population analysis.

Climacammina ferra Cummings, **new species**
Plate 1, figures 13-14; text-figure 16

Description: Test free, moderately large, straight or slightly curved, tapering and finely pointed in initial portion but subcylindrical in later part, with circular cross section; consists of some twelve slightly inflated, overlapping, stout biserially arranged chambers, followed by two or three strongly inflated uniserially arranged chambers, the last of which has a well marked domed terminal face; sutures rather broad and moderately depressed; septa in early portion thin and spatulate, later thicker and shorter; peripheral margin rounded and faintly lobulate; surface extremely rough and pitted; wall moderately thick, composed of a granular calcareous main element and well developed inner "fibrous" buttresses (often secondarily altered); aperture in the early portion a low lunate slit, in adult cribrate, consisting of some five or six circular holes on the terminal face of the last chamber.

Dimensions: Length of holotype 1.37 mm.; maximum breadth 0.55 mm.; length of biserial portion 0.6 mm.

Holotype: Slide 11319 in the Reserve and Study Collection, H.M. Geological Survey, Edinburgh Office, from the shales overlying the Charlestown Main Limestone, Lower Limestone Group, Lower Carboniferous, of Wilkieston Quarry, near Cupar, Fife, Scotland.

Paratype: Slide 11320 (thin section) in the same collection, from the same horizon and locality.

Comparison and affinities: The regular and even taper of the test, together with other internal details of morphology, distinguishes the juvenile forms of *Climacammina ferra* from adult specimens of *Cribrostomum scoticum*.

Population analysis: Analysis of a population of 152 specimens from a shale horizon at the type locality shows that the adult condition is represented by the climacamminoid (2) stage of chamber pattern (see text-figure 16).

Horizon and facies: Climacammina ferra is a rare form, known only from the No. 2 Limestone and equivalent horizons of the Lower Carboniferous in the eastern part of the Midland Valley of Scotland.

Climacammina patula (Brady)

Textularia (Bigenerina) patula BRADY, 1876 (part?), Monogr. Carb. and Permian Foram., pp. 136-137, pl. 8, figs. 10-11(?); pl. 10, figs 30-31.
Bigenerina patula (Brady) of authors.
Non Cribrostomum patulum (Brady) of Möller (1879) and other authors.

Description: Test free, small, stout, straight or slightly curved, tapering with rectangular cross section in early part, cylindrical with circular cross section in adult portion; consisting of some ten or eleven inflated, overlapping, subcuboidal biserially arranged chambers, gradually increasing in size as added, followed by two or three short, broad uniserially arranged chambers in the adult portion, with the first of these series only partly covering the terminal faces of the preceding pair of biserial chambers; sutures distinct and depressed throughout; peripheral margin lobulate; wall thick, composed of a granular calcareous main element and incomplete inner "fibrous" buttresses in later chambers; aperture in early portion a low lunate slit on inner margin, in later part cribrate, consisting of some seven or eight pores arranged more or less regularly on the terminal face of the last chamber.

Dimensions: Length of lectotype 1.1 mm.; maximum breadth 0.64 mm.; length of biserial portion 0.86 mm.

Lectotype: Ex Slide P.35420 in the Brady Collection of Carboniferous and Permian Foraminifera, British Museum (Natural History), from the Four Fathom Limestone, Lower Carboniferous, of Elfhills, Northumberland, England; figured by Brady (1876, pl. 10, fig. 30).

Comparison and affinities: Examination of the syntypes of *Textularia (Bigenerina) patula* Brady, 1876, in the British Museum (Natural History) shows that this species cannot be referred to *Bigenerina*. Of the two specimens figured by Brady (1876) on plate 10, one (fig. 30) possesses two uniserial chambers after an initial biserial portion, and, in the adult stage, has a cribrate aperture. (The latter condition can be made out from Hollick's accurate figures in the original monograph.) The supposed labyrinthic structure of the second specimen (fig. 31) is due to the irregularity of the internal septal surface and the cribrate nature of the septal openings. The specimens of *Textularia (Bigenerina) patula* figured by Brady (1876, pl. 8, figs. 10-11) are not present amongst the syntypes and figured specimens of the Brady Collection in the British Museum. Within the general collection there are two specimens that might be identified with the figures, but these were not collected from the same locality as the designated syntypes, and hence cannot be considered as paratypes. The specimen thought to be the one illustrated in figure 10 has a multiple aperture and is therefore not referable to *Bigenerina*, whilst that which seems to be the thin section, figure 11, is a lateral oblique longitudinal section that does not show the true development of the apertural condition.

On these grounds, Brady's species must be referred to *Climacammina*, and, to avoid confusion with the present wide usage of *Cribrostomum "patulum* (Brady)" of Möller (1879) in the U.S.S.R., the Russian form should be described as a new species.

Horizon and facies: Climacammina patula is a common and widespread form in the upper Visean of Britain, being confined to the calcareous shale facies.

In addition, the following species of *Climacammina* have been described previously:

Climacammina aljutovica Reitlinger, 1950;
Climacammina apliatula Reitlinger, 1950;
Climacammina cylindrica Cushman and Waters, 1928;
Climacammina? deckerelloides Lipina, 1948;
Climacammina elegantula Reitlinger, 1950;
Climacammina fragilis Reitlinger, 1950;
Climacammina grandis Reitlinger, 1950;
Climacammina ivanovae Reitlinger, 1950;
Climacammina keltmensis Reitlinger, 1950;
Climacammina lagenalis Lange, 1925;
Climacammina magna Roth and Skinner, 1930;
Climacammina moelleri Reitlinger, 1950;
Climacammina moelleri var. *timanica* Reitlinger, 1950;
Climacammina obsoleta Reitlinger, 1950;
Climacammina prisca Lipina, 1948;
Climacammina procera Reitlinger, 1950;
Climacammina protenta Schwager, 1883;
Climacammina sp. of Galloway in Galloway and Spock (1933);
Climacammina tenuicribrata Reitlinger, 1950;
Climacammina tudicla Lange, 1925;
Climacammina valvulinoides Lange, 1925;
Climacammina variana Lee, 1937; this is based on an oblique axial section of a *Climacammina*, and does not exhibit the full details of the sequence of apertures. Hence, the relationship of *Climacammina* and *Bigenerina* suggested by Lee is improbable.

Revision of earlier records by previous workers has led to the inclusion of further species in the genus:

Climacammina cushmani (Harlton), listed by Cushman and Waters (1928*a*) and based on *Cribrostomum cushmani* Harlton, 1928;
Climacammina elegans (Möller), listed by Reitlinger (1950) and based on *Cribrostomum elegans* Möller, 1879;
Climacammina lucilleae (Harlton), listed by Warthin (1930) and based on *Cribrostomum lucilleae* Harlton, 1927.

The present revision of earlier records leads to the inclusion of further species within the genus:

Cribrostomum brevis Reitlinger, 1950;
Cribrostomum gracile Möller, 1879;
Cribrostomum infundibulum Lee and Chen, 1930;
Cribrostomum laxum Lee and Chen, 1930;
Cribrostomum longissimoides Lee and Chen, 1930;
Bigenerina milchi Volz, 1904;
Bigenerina mitrata Trautschold, 1879;
Cribrostomum nelumboforme Lee and Chen, 1930;
Cribrostomum pyriforme Möller, 1879;
Cribrostomum spathulatum Lee and Chen, 1930;
Cribrostomum stiloforme Lee and Chen, 1930.

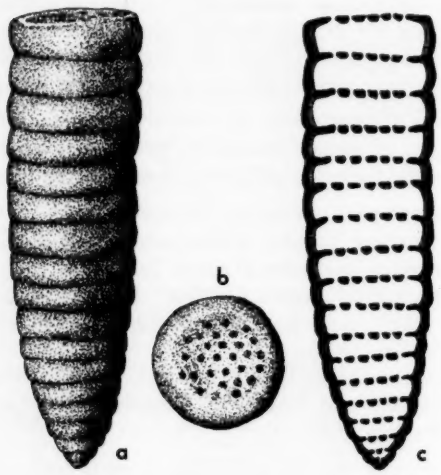
B. Upper Palaeozoic species that may be referable to *Climacammina:*

The following species are based on thin sections in limestone, and require further study to determine their true systematic position:

Climacammina bicammina Lange, 1925;
Climacammina cribrigera Schwager, 1883;
Climacammina obscura Reitlinger, 1950;
Climacammina (misspelt *Climacamina*) *simplex* Meunier, 1888.

The following species have been referred to in Russian literature, but the author has no details as to their morphology or validity:

Climacammina inperta Reitlinger, mentioned by Reitlinger (1950);
Climacammina elegans (Möller) var. *multithyris*, mentioned by Mikhailov (1935);
Climacammina forschi, mentioned by Mikhailov (1935);
Climacammina fursenko, mentioned by Mikhailov (1935).



TEXT-FIGURE 17

Cribrogenerina sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen; c, longitudinal axial section.

Genus **Cribrogenerina** Schubert, 1907
Text-figure 17a-c

Bigenerina d'Orbigny. – Volz (1904) and other authors (in part).

Type species: Cribrogenerina sumatrana (Volz) of Schubert (1907) = *Bigenerina sumatrana* Volz, 1904.

Description: Test free, straight or slightly curved, enlarging rapidly in initial portion, thereafter cylindrical or gradually tapering; chambers numerous, closely appressed, short and broad in form, circular or ellipsoidal in cross section; except for the first four or five chambers, which may be biserial in arrangement, chambers uniserial throughout, after a spherical proloculum; septa formed by incurving of test wall, with multiple septal openings in the form of rounded pores; sutures distinct, often broad and depressed; peripheral margin faintly to strongly lobulate; surface usually rough and granular; wall composed of a granular calcareous main element, together with an inner "fibrous" layer and an incomplete, patchy agglutinate external coating, which may be absent; aperture in biserial portion (if this be present) a low lunate slit, otherwise and in all uniserial chambers cribrate, consisting of numerous rounded holes on the domed face of the last chamber.

In thin section, representatives of this genus may be identified, in axial section only, by the characteristic layered wall structure and the sequence of chamber and apertural patterns (see text-figure 17a-c).

Ontogeny: The microspheric generation of some forms, such as *Cribrogenerina wysogorskyi* (Volz) and *Cribrogenerina krizi* Cushman, has a small biserial nepionic stage following the spherical proloculum. Usually, however, this biserial stage is omitted, and the proloculum is followed immediately by the short, broad, circular chambers with multiple apertures, which continue through to the adult stage with gradual increases in volume.

Comparison and affinities: Schubert (1907) regarded *Cribrogenerina* as a direct derivative of *Climacammina*, by the progressive reduction and eventual elimination of the early biserial portion. It is distinguished from *Monogenerina* by the cribrate nature of the aperture, and from similar genera outside the Palaeotextulariidae, such as *Nodosinella* and *Geinitzina*, by a difference of wall structure and the cribrate condition of the aperture.

Horizon and facies: Cushman (1948) and Glaessner (1945) list the range of *Cribrogenerina* as Carboniferous and Permian. It should be noted, however, that this genus is essentially a Permian form, being common in the United States and even more so in the Orient. Many records of its occurrence in the Carboniferous, such as that of Liebus (1931), are incorrect and are based on lateral longitudinal sections of *Climacammina*. It would seem that *Cribrogenerina* was not developed until the uppermost Carboniferous, if not the Lower Permian.

A. Upper Palaeozoic species referable to *Cribrogenerina:*

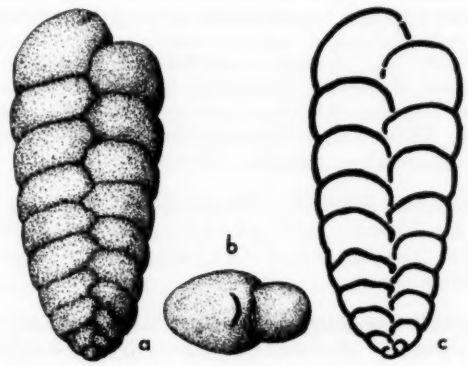
Cribrogenerina krizi Cushman, 1942;
Cribrogenerina leonhardi (Volz), based on *Bigenerina leonhardi* Volz, 1904;
Cribrogenerina sumatrana (Volz), listed by Schubert (1907) and based on *Bigenerina sumatrana* Volz, 1904;
Cribrogenerina wysogorskyi (Volz), listed by Schubert (1907) and based on *Bigenerina wysogorskyi* Volz, 1904.

B. Upper Palaeozoic species that may be referable to *Cribrogenerina:*

The following species are based on thin sections in limestone, and require further study to determine their true systematic position:

Cribrogenerina climacamminoides Lange, 1925;
Cribrogenerina macillenta Lange, 1925;
Cribrogenerina nitida Lee and Chen, 1930;
Cribrogenerina obesa Lange, 1925;
Cribrogenerina permica Lange, 1925;
Cribrogenerina sp. of Huzimoto (1936);
Cribrogenerina verbeeki Lange, 1925;
Cribrogenerina vermiculata Lange, 1925.

Thus, in the case of *Cribrogenerina climacamminoides* Lange, 1925, the type material is not a true axial section, and hence does not show the full details of the morphology. It is a low, oblique tangential section, lying subparallel and laterally to the axial plane. As a result, the apertures are not shown in many of the chambers, and there is the "duplication of the third chamber" referred to by Lange. This may well be a *Climacammina* of a form similar to *Climacammina valvulinoides* Lange, 1925, when seen in true axial section.



TEXT-FIGURE 18

Deckerellina sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen (figs. 18a and b are reconstructions from study of thin sections); c, longitudinal axial section showing granular calcareous element without external agglutinate coating.

Genus **Deckerellina** Reitlinger, 1950
Text-figure 18a-c

Type species: Deckerellina istiensis Reitlinger, 1950.

Description: Test small, straight or slightly curved, enlarging rapidly in initial portion, thereafter gradually tapering, ellipsoidal in cross section; consisting of numerous short, broad biserially arranged chambers, after a spherical proloculum; septa strongly curved and often overlapping; sutures distinct and depressed; peripheral margin faintly lobulate; surface smooth or finely granular; wall composed of a granular calcareous main element, with an incomplete, patchy agglutinate external coating, which may be absent; aperture in early portion a simple, single low lunate opening, but in later part formed of two elongate slits, one on the inner part of the terminal face of the last chamber and the other lying below, on the inner margin.

In thin section, representatives of this genus may be identified, in axial section only, by the characteristic wall structure and the double nature of the aperture in the ephebic portion of the test (see text-figure 18a-c).

Comparison and affinities: Deckerellina occupies an anomalous position within the Palaeotextulariidae. When the apertural sequence is considered, it shows an affinity to *Deckerella*, and some species of the latter possess a neanic stage whose apertural characters are the same as those of the adult *Deckerellina*. But on other morphological grounds, including the form and pattern of the chambers and septa, especially the latter, *Deckerellina* seems to be closely related to some Visean species of *Palaeotextularia*. In the adult condition it may be distinguished from these by the double nature of the aperture.

Horizon and facies: This genus is known only from the Middle Carboniferous of the U.S.S.R. and from the upper Visean of Britain, where it has been identified, in the course of the present study, as thin sections in limestone.

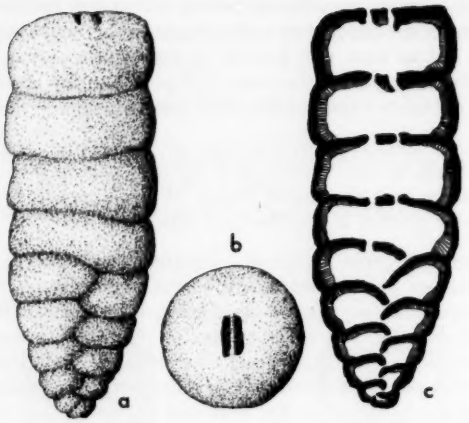
UPPER PALAEOZOIC SPECIES REFERABLE TO *Deckerellina:*

Deckerellina istiensis Reitlinger, 1950;
Deckerellina mirabilis Reitlinger, 1950.

Genus **Deckerella** Cushman and Waters, 1928
Text-figure 19a-c

Type species: Deckerella clavata Cushman and Waters, 1928*a*.

Description: Test free, elongate, tapering in early portion, cylindrical or gradually tapering in later part, oval to circular in cross section; consisting of slightly inflated, overlapping biserially arranged chambers, after a spherical proloculum, followed by short, broad, inflated uniserially arranged chambers; sutures usually distinct and depressed; peripheral margin faintly lobulate, becoming strongly so in later part; surface rough and pitted, or granular; wall relatively thick, composed of a main granular calcareous element, showing dark in transmitted light, together with an incomplete inner "fibrous" layer in the form of linings or buttresses in the lateral parts of the chambers, and also a thin impersistent coating of agglutinate material on or embedded in the exterior surface, which is not always present; aperture in the early part a low lunate slit opening at the base of the terminal face on the inner margin, later moving into a central position on the terminal face as two parallel slits or ellipsoidal openings separated by a narrow partition.



TEXT-FIGURE 19

Deckerella sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen; c, longitudinal axial section cut at right angles to the long diameter of the apertures.

In thin section, representatives of this genus may be identified only in an axial section cut in a plane at right angles to the long diameter of the apertural openings, by the characteristic wall structure and the sequence of chamber and apertural patterns (see text-figure 19).

Ontogeny: Cushman and Waters (1928*a*), in their detailed description of the ontogeny of *Deckerella,* noted that the initial palaeotextularioid stage is followed immediately by the climacamminoid stage, the latter possessing a double apertural condition. It would seem, therefore, that the cribrostomoid stage is not represented in the transition from one chamber pattern to the other. Nevertheless, this transitional period is shown in several species by the occurrence of a double aperture in the final chambers of the biserial series. Such a condition of the neanic stage may be compared with that of the adult *Deckerellina.*

Comparison and affinities: The double nature of the aperture in the adult form distinguishes *Deckerella* from *Climacammina* on the one hand, and *Palaeobigenerina* on the other.

Horizon and facies: Deckerella occurs as a rare form in the middle and upper Visean of Britain. It is present in the Pennsylvanian of the United States and in the Lower and Middle Carboniferous of the U.S.S.R.

Warthin (1930) suggested that the wall structure of *Deckerella laheei* varied with environment. This would seem to be true only insofar as the external coating of adventitious material is concerned, it being better developed in sandy sediments than in non-sandy deposits. There is no indication that the granular calcareous layer or the inner "fibrous" layer varies in different environments.

UPPER PALAEOZOIC SPECIES REFERABLE TO *Deckerella:*

Deckerella quadrata Cummings, **new species**
Plate 1, figure 15

Description: Test relatively large, straight or slightly curved, early portion smoothly tapering with squarish to rectangular cross section, later portion subcylindrical; consisting of some fourteen overlapping biserially arranged chambers, followed by one or two short, broad, slightly inflated uniserially arranged chambers with rather squarish cross section; sutures distinct, narrow and depressed, especially in later portion; periphery faintly to sharply lobulate and with angled edges; surface rough and pitted; wall relatively thick, composed of a granular calcareous main element and incomplete inner "fibrous" buttresses in the majority of later chambers; aperture distinct, in central position on inflated terminal face, consisting of two hemispherical to ellipsoidal openings arranged with long axes parallel; aperture in early portion a low lunate slit.

Dimensions: Length of holotype 1.82 mm.; maximum breadth 0.83 mm.; length of biserial portion 1.1 mm.

Holotype: Slide P.3602 in the Protozoa Collection, Department of Geology, University of Glasgow, from the shales overlying the Main Limestone, Lower Limestone Group, Lower Carboniferous, of Brockley, near Lesmahagow, Lanarkshire, Scotland.

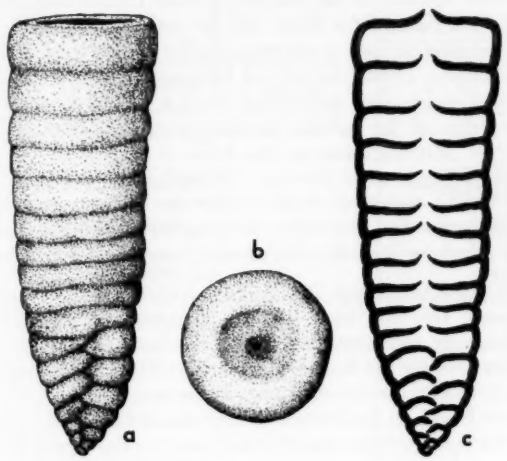
Comparison and affinities: The quadrate nature of the test and the relatively short uniserial portion distinguish this species from the forms described from the American Pennsylvanian.

Preservation and matrix: In the type material, the test wall has undergone secondary alteration by iron enrichment of the granular calcareous layer, and the inner "fibrous" buttresses have been recrystallised in the majority of cases to an irregular mosaic of clear calcite.

Horizon and facies: This species has been recorded as a rare form confined to the calcareous shale facies from several localities in the lower part of the Lower Limestone Group, Lower Carboniferous, of Lanarkshire and Ayrshire.

In addition, the following species of *Deckerella* have been described previously:

Deckerella clavata Cushman and Waters, 1928;
Deckerella composita Reitlinger, 1950;
Deckerella dvinensis Reitlinger, 1950;
Deckerella goessi Roth and Skinner, 1930;
Deckerella gracilis Reitlinger, 1950;
Deckerella laheei Cushman and Waters, 1928;
Deckerella mjachkovensis Reitlinger, 1950;
Deckerella tenuissima Reitlinger, 1950.



TEXT-FIGURE 20

Palaeobigenerina sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen; c, longitudinal axial section.

Genus **Palaeobigenerina** Galloway, 1933
Text-figure 20a-c

Bigenerina d'Orbigny. – SCHELLWIEN (1898) and other authors (in part).

Type species: Palaeobigenerina geyeri (Schellwien) of Galloway (1933) = *Bigenerina geyeri* Schellwien, 1898.

Description: Test free, straight or slightly curved, elongate, gradually tapering or tapering in early portion and cylindrical in later part; consisting of a spherical proloculum succeeded by a short biserial stage with chambers overlapping in palaeotextularioid manner, and this, in turn, succeeded by numerous short, broad, slightly inflated uniserially arranged chambers with circular cross section; septa formed by incurving of test wall, variable in shape, curvature and thickness, often with shallow neck; sutures distinct and depressed; peripheral margin usually faintly lobulate; surface moderately rough, often granular; wall composed of a granular calcareous main element with an incomplete inner "fibrous" layer in the form of linings or buttresses, together with a thin, impersistent agglutinate veneer on or embedded in the exterior surface, which may be absent; aperture in early biserial part a low, lunate slit, but throughout uniserial portion a single simple circular opening in central part of domed terminal face of chamber.

In thin section, representatives of this genus may be identified, in axial section only, by the characteristic wall structure and the sequence of chamber and apertural patterns (see text-figure 20a-c).

Comparison and affinities: Palaeobigenerina is distinguished from *Bigenerina* by the fundamental differences of wall structure that exist between the two. The possession of a single simple aperture in the ephebic stage distinguishes *Palaeobigenerina* from *Deckerella* on the one hand, and *Climacammina* on the other.

Preservation and matrix: Examination of paratype material suggests that the unusual wall structure noted by Plummer (1945) in the case of *Bigenerina perexigua* is not an original structure. In this species, Plummer describes the wall as being "composed of quartz grains so neatly fitted, that the surface is not sharply rugose, though granules are rather large." Such a composition and texture may result from secondary silicification of the host sediment, as indicated by Cummings (1955*b*) in the case of *Lugtonia*.

Horizon and facies: Palaeobigenerina is a rare form in the Visean and Namurian of western Europe, but is more common in the Pennsylvanian of the United States, the Upper Carboniferous of the U.S.S.R., and the Permian of America and the Orient.

UPPER PALAEOZOIC SPECIES REFERABLE TO *Palaeobigenerina:*

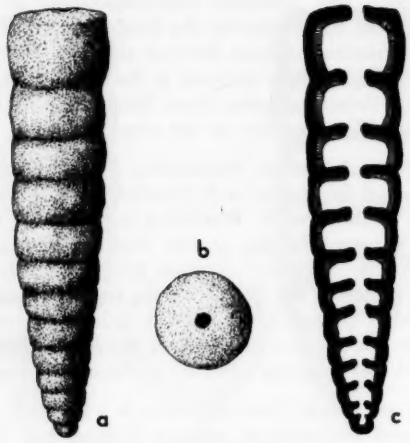
Palaeobigenerina cucumis (Lange), based on *Bigenerina cucumis* Lange, 1925;
Palaeobigenerina geyeri (Schellwien), listed by Galloway (1933); based on *Bigenerina geyeri* Schellwien, 1898;
Palaeobigenerina perexigua (Plummer), based on *Bigenerina perexigua* Plummer, 1945;
Palaeobigenerina sp., based on *Bigenerina* sp. of Schellwien (1898).

Genus **Monogenerina** Spandel, 1901
Text-figure 21a-c

Type species: Monogenerina atava Spandel, 1901, designated by Cushman (1928*a*).

Description: Test free, elongate, straight or slightly curved, cylindrical or slowly tapering; consisting of a series of inflated, distinct, simple uniserially arranged chambers gradually increasing in size as added and showing little or no overlapping; sutures distinct and depressed; peripheral margin lobulate and circular in cross section; surface somewhat rough or granular; wall relatively thick, composed of a granular calcareous main element, together with an often incomplete inner "fibrous" layer and an indistinct outer veneer of agglutinated material, which may be absent; aperture throughout a simple, circular, large opening in a central position on the terminal face, often with a slight neck.

In thin section, representatives of this genus may be identified, in axial section only, by the characteristic wall structure and the chamber and apertural arrangements (see text-figure 21a-c).



TEXT-FIGURE 21

Monogenerina sp., diagrams showing typical appearance: a, lateral view of complete specimen; b, apertural view of complete specimen; c, longitudinal axial section.

Ontogeny: Cushman (1948) suggested that the earliest chambers of the microspheric generation are often biserial, but this requires verification. Usually the test arises from a spherical proloculum and develops throughout in a uniserial pattern by a gradual increase in chamber volume.

Comparison and affinities: In his original definition of the genus, Spandel (1901) described the wall as "sandig oder kalkig." Later records indicate the twofold nature of the wall structure, and examination of forms closely similar to *Monogenerina atava* Spandel leads to the description given above.

This genus would seem to be closely similar to *Nodosinella* Brady, 1876, as revised and re-described by Cummings (1955*b*). The most significant morphologic difference is the presence of an outer agglutinate layer in most species of *Monogenerina* and its absence in *Nodosinella*. Further study may show that *Monogenerina* should be included, as a synonym, in *Nodosinella*, but in this present work they are considered distinct.

Several uniserial genera have been described from the Permian, and *Nodosinella* and *Monogenerina* are but two of these. Others include *Lunucammina* Spandel, 1898, *Geinitzina* Spandel, 1901, *Pachyphloia* Lange, 1925, *Padangia* Lange, 1925, *Spandelina* Cushman and Waters, 1928, *Spandelinoides* Cushman and Waters, 1928, *Pleurostomelloides* Majzon, 1943, and *Syzrania* Reitlinger, 1950. Confusion over the type species of *Geinitzina*, and lack of detailed morphologic analysis, render accurate comparison with *Monogenerina* impossible, even though Spandel considered them distinct. *Pachyphloia* and *Padangia* are known only from thin sections which lack full structural details, but they appear to differ from *Monogenerina* both in the structure of the wall and in the chamber arrangement. *Spandelina* may be distinguished from *Monogenerina* by the form of the septa and the sutural pattern. *Pleurostomelloides* and *Lunucammina* are imperfectly known. Galloway (1933) considered *Spandelinoides* as a synonym of *Monogenerina*, and further study is needed to assess the validity of the former. *Syzrania* is readily distinguished from *Monogenerina* on the basis of wall structure, the former having an external "fibrous" layer and an inner granular calcareous layer. Within the Palaeotextulariidae, *Monogenerina* resembles *Cribrogenerina* but is distinguished by the cribrate apertural condition of the latter.

Horizon and facies: This genus is confined to the Permian, being recorded from Europe, America, and the Orient. Recently, representatives have been identified in the British Permian for the first time. Galloway (1933) recorded this genus as present in the Lower Palaeozoic, but these records are based on Galloway's conception of the genus, which was much greater than that indicated by the type material.

A. Upper Palaeozoic species referable to *Monogenerina:*

Monogenerina atava Spandel, 1901;
Monogenerina gradata Lange, 1925;
Monogenerina grandis Warthin, 1930;
Monogenerina nodosariformis Spandel, 1901.

B. Upper Palaeozoic species not referable to *Monogenerina*, whose correct generic placing is known:

Monogenerina pyramidis Chapman and Howchin, 1905, listed as *Nodosaria pyramidis* (Chapman and Howchin) by Chapman, Howchin and Parr (1934);

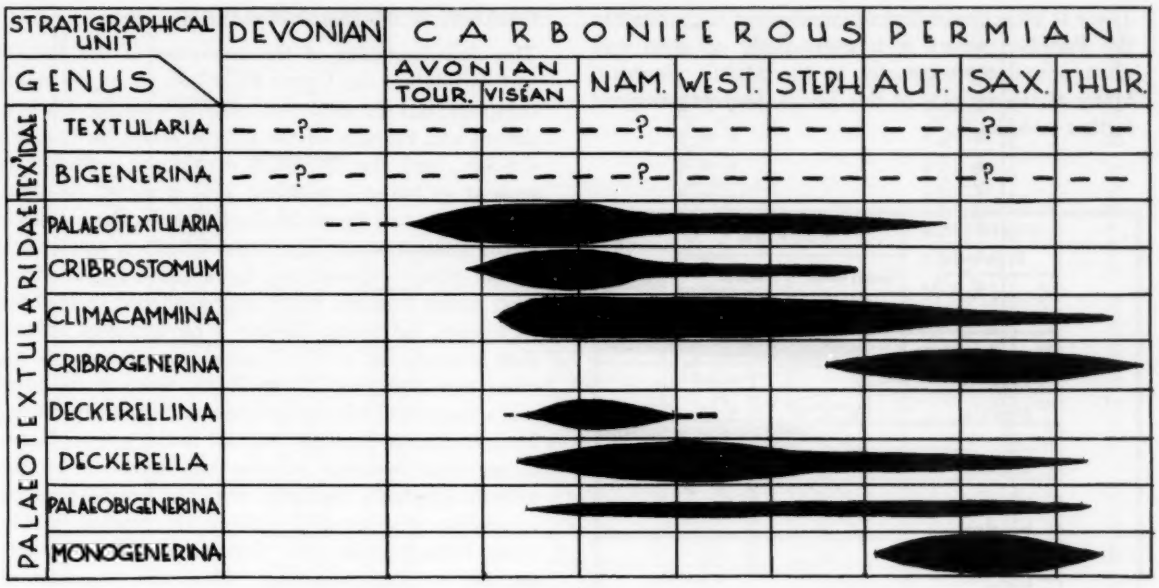
Monogenerina texana Cushman and Waters, 1928, listed as a synonym of *Spandelina texana* Cushman and Waters, 1928.

STRATIGRAPHIC DISTRIBUTION

General

The approximate stratigraphic ranges of the Upper Palaeozoic textulariid foraminifera are summarised in chart form in text-figure 22. This chart is based on their world-wide occurrence, as recorded in previous literature, with modifications arising from the present revision. Thus, for example, many of the records of *Cribrostomum* in the Upper Carboniferous are based either on non-axial sections of *Climacammina* or on juvenile forms of the latter genus.

This distribution is characterised by the successive and rapid incoming of new and more highly developed genera in the upper Tournaisian and Visean. Because



TEXT-FIGURE 22

Chart showing approximate absolute and quantitative distribution of genera of the Palaeotextulariidae within the Upper Palaeozoic, against the European time-scale. Upper Palaeozoic representatives of the Textulariidae are included, but without reference to their relative abundance.

of this, the family possesses a significant value in the interpretation of Lower Carboniferous stratigraphy.

Palaeotextularia seems to appear in the uppermost Devonian and to continue as a relatively rare form through the lower Tournaisian. Thereafter, it becomes more abundant and widespread, being particularly common in the Visean. The early forms of the genus lack the inner "fibrous" layer of the wall structure, this unit appearing only in middle Visean and later species. Upper Carboniferous assemblages show a progressive decrease in the frequency of *Palaeotextularia*, and, although it extends into the Permian, many of the Permo-Carboniferous records are based on the palaeotextularioid condition of later genera rather than on the genus itself.

Cribrostomum appears in the upper part of the Tournaisian and is the dominant palaeotextulariid in the lower and middle Visean. Thereafter it exhibits a diminishing frequency, and is extinct before the Permian. Many of the records of its occurrence in the Upper Carboniferous are based on the cribrostomoid condition of the juvenile stages of such genera as *Climacammina*.

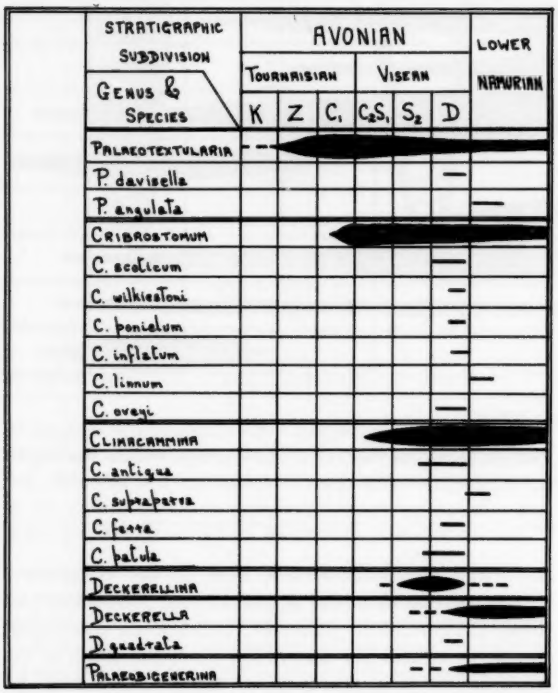
Climacammina appears in the lower part of the middle Visean, develops rapidly in morphologic variety and numerical abundance, and is the commonest palaeotextulariid in the upper Visean, Namurian, and later Carboniferous intervals. There is no doubt that it continues into the Lower Permian, but some of the records of its appearance at higher levels may be based on the climacamminoid condition exhibited in the juvenile stages of the microspheric generations of some species of *Cribrogenerina*.

Although *Cribrogenerina* may occur in the uppermost Carboniferous, it is predominantly a Permian form, and is particularly common in the upper part of the Lower Permian.

Deckerellina, a relatively rare form, is as yet known only from the upper Visean and Namurian of Britain and the U.S.S.R. In contrast, *Deckerella* is more widespread, being present in the middle Visean of the U.S.S.R., and being recorded in the British upper Visean for the first time in this present study. Essentially, however, *Deckerella* is an Upper Carboniferous form, common in the American Pennsylvanian, whose Permian records require further documentation.

Palaeobigenerina is a very rare form, which appears for the first time in the Visean and is known in the American Pennsylvanian. It is somewhat more numerous in the Permian but has little stratigraphic value.

There is little doubt that *Monogenerina* is confined to the Permian, where it is particularly common and often abundant, especially in the Middle Permian. Many of the records of this genus, however, require further revision.



TEXT-FIGURE 23

Chart showing the distribution of palaeotextulariids in the British Lower Carboniferous and Namurian, excluding specific variants identified only in thin sections of limestone. (Note: The use of Vaughan's zones and the term "Avonian" in relation to the terms "Tournaisian" and "Visean" is an approximation, and represents a temporary expedient.)

British Lower Carboniferous

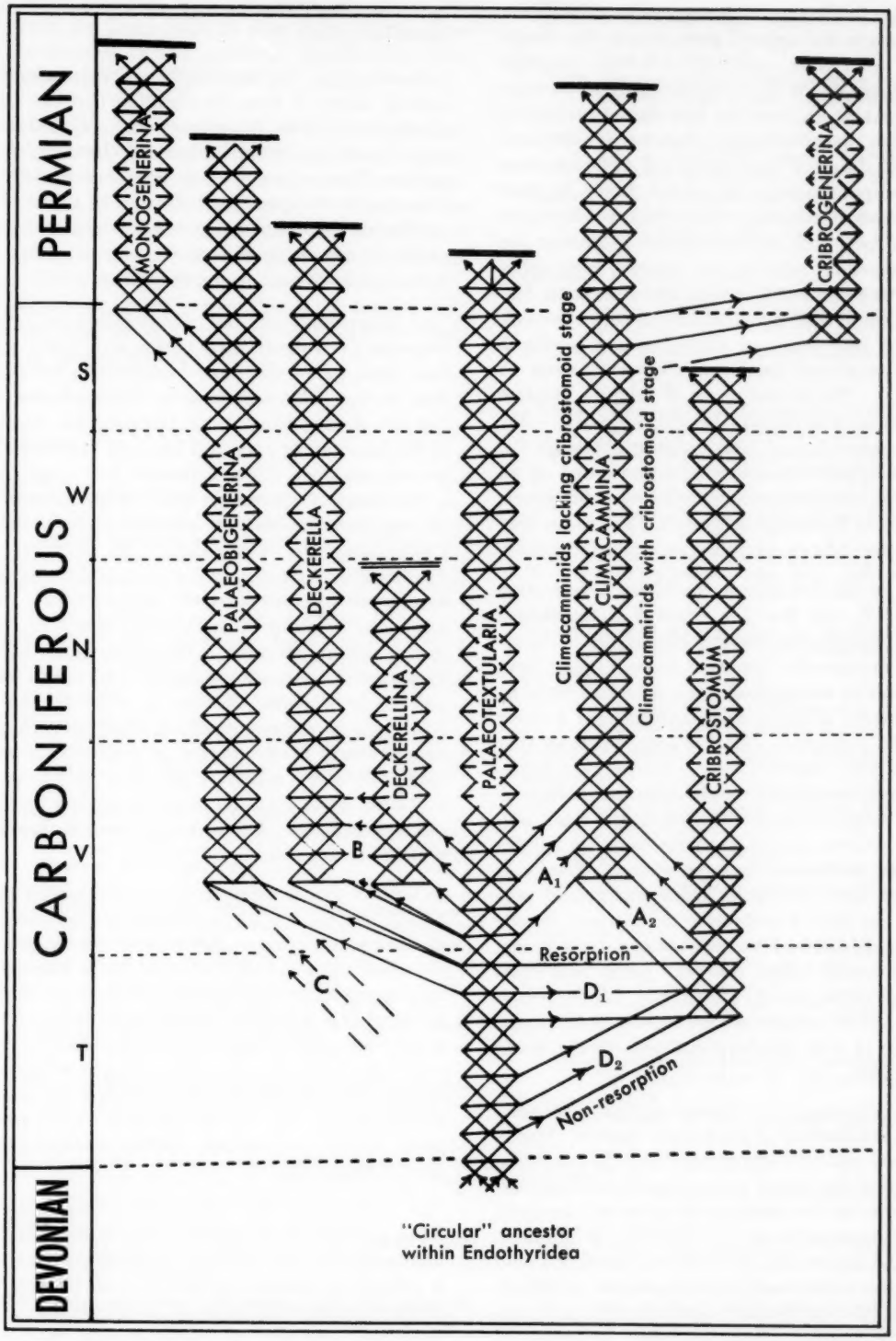
The distribution of the Palaeotextulariidae in the British Lower Carboniferous and Namurian is summarised in chart form (text-figure 23). This summary is confined, on the one hand, to the absolute and quantitative occurrence of the genera as revealed by the analysis of washed samples and thin sections of limestone, and on the other hand to the absolute range only of the species identified from washed samples. It does not include a record of the many specific variants recognisable in thin-section analysis.

PHYLOGENY OF THE PALAEOTEXTULARIIDAE

The documentation of the evolution of the Palaeotextulariidae in the Upper Palaeozoic is by no means complete, but the evidence collated from the Carboniferous and Permian of the United States, Britain, the U.S.S.R., and the Orient is considered sufficient to present an initial hypothesis. This is shown diagrammatically in text-figure 24. Superficially, the evolution of the Palaeotextulariidae seems to follow a relatively simple plan. Characterised by a distinct wall structure, which remains stable and unaltered throughout its history, the group displays a phylogenetic pattern that is expressed in the successive variations of the other two important biocharacters, those of the form and arrangement of the chambers and of the apertures. Thus, a change from the biserial to the uniserial condition, accompanied by the development of the cribrate apertural condition from the lunate, through successive stratigraphic horizons, is typified in the series *Palaeotextularia — Cribrostomum — Climacammina — Cribrogenerina*. When the sequence of chamber conditions remained the same, but the bioseries of apertural pattern became stabilised after the development of the double condition, the series *Palaeotextularia — Deckerellina — Deckerella* resulted. In like manner, stabilisation of the apertural character prior to the double condition led to the *Palaeotextularia — Palaeobigenerina — Monogenerina* series. Such a concept of the evolution of the group is close to that proposed by Schubert (1907) and later employed by Cushman (1928*a*) in his classification of the order. It implies that the phylogeny is linear and is reflected in the bioseries of chamber form and pattern.

Although *Palaeotextularia* must be considered the root stock from which later genera arose, the origin of the family is unknown. The presence of a "circular" stage in the embryonic portions of some species of *Palaeotextularia* indicates a coiled ancestor, but the evidence is insufficient to show whether this coiling is planispiral or trochospiral. Recognising the fundamental significance of the wall structure, it is assumed that the Palaeotextulariidae arose from a coiled member of the ancestral stock of the Endothyridea.

Palaeotextularia is present in the uppermost Devonian and Tournaisian as a relatively small, rare, indistinct form possessing a uni-layered wall of the granular calcareous type. Its later evolution in the upper Tournaisian and the Visean is characterised by increase in size, by the development of a multi-layered wall structure, and, in some instances, by a tendency for resorption to occur in the younger parts of the test.



TEXT-FIGURE 24

Diagram of the suggested phylogeny of the Palaeotextulariidae, set against the European time-scale; T = Tournaisian; V = Visean; N = Namurian; W = Westphalian; S = Stephanian.

There is little doubt that *Palaeotextularia* gave rise to *Cribrostomum* in the upper Tournaisian by the development of a cribrate apertural condition together with asymmetry of the final chamber and an increase in size. It would seem, however, that this was achieved, not by simple linear evolution, but by development along several different lines. Species of *Cribrostomum* showing resorption seem to be related closely, in other aspects of their morphology and in their stratigraphic position, to species of *Palaeotextularia* exhibiting the same phenomenon, and yet are distinct from other species of *Cribrostomum* lacking the resorption feature. In the same way, there appears to be a close link between the rare forms of *Cribrostomum* having a uni-layered test, and species of *Palaeotextularia* so characterised. The varied mode of origin is implied in the chart (text-figure 24) by the trends $D_1 - D_2$. The further evolution of *Cribrostomum*, through the Visean and Upper Carboniferous, is patterned on an interplay of such trends within the limits of the genus, and reaches its fullest expression in those forms that possess a final cribrate chamber arranged uniserially.

Appearing for the first time in the Mikhailo formation of the U.S.S.R. and the C_2S_1 interval of the British Avonian, *Climacammina* follows closely after *Cribrostomum* in stratigraphic sequence. Since it differs from the latter only in the multi-chambered condition of its uniserial portion, it might well be considered a direct phylogenetic derivative. But evidence indicates that the pattern was manifold. Some species of *Climacammina* possess a cribrostomoid A chamber pattern in the neanic stage, immediately prior to the adult uniserial part. Others possess a cribrostomoid B pattern in this stage, and some, by a pronounced change of growth rate after the earlier palaeotextularioid portion, seem to lack a cribrostomoid pattern in the neanic stage. This may be a result of the development of *Climacammina* along different paths and from different ancestral stocks (text-figure 24, $A_1 - A_2$). Reitlinger (1950) recognises trends of development on the basis of wall structure, and regards the genus as polyphyletic.

The later phylogeny of *Climacammina* is characterised by a reduction of the biserial portion. Visean forms usually exhibit a climacamminoid (2) condition, whilst those of the Upper Carboniferous show successive increases in the number of uniserial chambers until the climacamminoid (5) condition is attained. Although the sequence is poorly documented, it would seem that this trend leads to the evolution of *Cribrogenerina* in the uppermost Carboniferous and continues in the Permian within the genus, accompanied by other trends such as that of the multiplication of apertural pores.

Acknowledging the importance of the anomalies described above, it must be admitted that the inferred phylogeny of the *Palaeotextularia — Cribrogenerina* series is reflected in the bioseries of chamber form and pattern. This is a result of the dominance of that biocharacter in the genetic constitution of the stock (see section on "Morphology"), which tends to mask the manifold nature of the phylogeny and lead to an oversimplification of its interpretation.

The description of the *Deckerellina — Deckerella* sequence (text-figure 24B) tacitly accepts the concept that these follow the same bioseries of chamber pattern as the *Palaeotextularia — Cribrogenerina* series, but are distinguished by a phylogenetic retardation of the bioseries of apertural form. As indicated above, present evidence shows anomalies that question such a hypothesis. *Deckerellina* and *Deckerella* appear for the first time at about the same stratigraphic horizon. Discounting the biocharacter of apertural form, *Deckerellina* is closely similar to several contemporary species of *Palaeotextularia*. In the same way, *Deckerella* is more akin to *Climacammina*, except in the case of the double aperture, a condition which has been identified in the neanic stage of both *Climacammina* and *Cribrostomum*. *Deckerella* exhibits the same variations of cribrostomoid chamber pattern in the neanic stages of its species as does *Climacammina*. *Deckerellina* is a relatively rare form, and there is not the same documentation of the transition to *Deckerella* — if any exist — as there is between *Cribrostomum* and *Climacammina*.

In view of this, it seems reasonable to suggest that the double aperture is not a stabilised condition of the biocharacter typifing a distinct stock, but is present in the adult stage of sufficient numbers to warrant separate recognition. This relative abundance may be a result of this particular biocharacter attaining a temporary increase in dominance within the stock. This occurred rarely in the *Palaeotextularia* gens, and, when it did, *Deckerellina* resulted. It happened more frequently in the *Cribrostomum — Climacammina* gens, possibly on several distinct occasions, giving rise to *Deckerella*.

The evolution of the *Palaeobigenerina — Monogenerina* series is poorly documented in the Carboniferous because of the rarity of *Palaeobigenerina*, and it is difficult to interpret in the Permian because of the confused systematic status of *Monogenerina*. There is little doubt that they are related genera, and the origin

of *Palaeobigenerina* may find close parallel in that suggested for *Deckerella*. It may arise directly from *Palaeotextularia* or, by apertural modification, from *Climacammina* (text-figure 24C).

This concept of the phylogeny of the Palaeotextulariidae considers the evolution of the group as a plexus of descent in which each genus represents a common and particular combination of conditions of the several biocharacters constituting the members of the group. Since such combinations can be achieved along different lines, the genus must be regarded as a morphologic group rather than as a natural unit, and the bioseries as a guide rather than a true indicator of the evolutionary history.

BIBLIOGRAPHY

BRADY, H. B.
1871 – See YOUNG, J., AND ARMSTRONG, J.

1873 – In: ETHERIDGE, R., JR., *Notes on certain genera and species mentioned in the foregoing lists*. Scotland, Geol. Survey, Mem., Expl. Sheet 23, appendix 2, pp. 93-107.

1876 – *A monograph of Carboniferous and Permian foraminifera (the genus Fusulina excepted)*. Palaeontogr. Soc. London, Monogr., vol. 30, pp. 1-166, pls. 1-12.

1884 – *Report on the foraminifera dredged by H.M.S. Challenger, during the years 1873-1876*. Challenger Exped. 1873-1876, Rept., Zool., vol. 9, pp. 1-814, pls. 1-115 (in atlas).

CHAPMAN, F., AND HOWCHIN, W.
1905 – *A monograph of the foraminifera of the Permo-Carboniferous limestones of New South Wales*. New South Wales, Geol. Survey, Mem., Pal., no. 14, pp. 1-22, pls. 1-4.

CHAPMAN, F., HOWCHIN, W., AND PARR, W. J.
1934 – *A revision of the nomenclature of the Permian foraminifera of New South Wales*. Roy. Soc. Victoria, Proc., new ser., vol. 47, pt. 1, pp. 175-189.

CHERNYSHEVA, N. E.
1940 – *On the stratigraphy of the Lower Carboniferous foraminifera in the Makarovsk District of the South Urals*. Soc. Nat. Moscou. Bull., new ser., vol. 48 (Sect. Géol., vol. 18), no. 5-6, pp. 113-135, pls. 1-2, tfs. 1-5.

1948 – *Stratigraphic subdivision of the Visean stage in the Makarovsk region, southern Urals, on the basis of foraminifera*. Akad. Nauk S.S.S.R., Inst. Geol. Nauk, Trudy, vol. 62 (Geol. Ser., no. 19), pp. 90-101.

COOPER, C. L.
1947 – *Upper Kinkaid (Mississippian) microfauna from Johnson County, Illinois*. Jour. Pal., vol. 21, pp. 81-94, pls. 19-23, tf. 1, tables 1-3.

CRESPIN, I., AND PARR, W. J.
1940 – *Arenaceous foraminifera from the Permian rocks of New South Wales*. Roy. Soc. New South Wales, Jour. Proc., vol. 74, pp. 300-311, pls. 12-13.

CUMMINGS, R. H.
1955*a* *New genera of foraminifera from the British Lower Carboniferous*. Washington Acad. Sci., Jour., vol. 45, no. 1, pp. 1-8, tfs. 1-5.

1955*b* *Nodosinella Brady, 1876, and associated Upper Palaeozoic genera*. Micropaleontology, vol. 1, no. 3, pp. 221-238, pl. 1, tfs. 1-10.

CUSHMAN, J. A.
1928*a* *Foraminifera, their classification and economic use*. Cushman Lab. Foram. Res., Spec. Publ., no. 1, pp. 1-401, pls. 1-59.

1928*b* *The designation of some genotypes in the foraminifera*. Cushman Lab. Foram. Res., Contr., vol. 3, pt. 4, pp. 188-190.

1948 – *Foraminifera, their classification and economic use*. Ed. 4. Cambridge, Mass.: Harvard Univ. Press, pp. 3-605, pls. 1-31, tfs. 1-9; Key, pls. 1-55.

CUSHMAN, J. A., AND STAINBROOK, M. A.
1943 – *Some foraminifera from the Devonian of Iowa*. Cushman Lab. Foram. Res., Contr., vol. 19, pt. 4, pp. 73-79, 1 pl.

CUSHMAN, J. A., AND WATERS, J. A.
1927 – *Arenaceous Paleozoic foraminifera from Texas*. Cushman Lab. Foram. Res., Contr., vol. 3, pt. 3, pp. 146-150, pls. 26-27.

1928*a* *The development of Climacammina and its allies in the Pennsylvanian of Texas*. Jour. Pal., vol. 2, pp. 119-130, pls. 17-19.

1928*b* *Additional Cisco foraminifera from Texas*. Cushman Lab. Foram. Res., Contr., vol. 4, pt. 3, pp. 62-67, pl. 8.

1928*c* *Upper Paleozoic foraminifera from Sutton County, Texas*. Jour. Pal., vol. 2, pp. 358-372, pls. 47-49.

1928*d* *Some foraminifera from the Pennsylvanian and Permian of Texas*. Cushman Lab. Foram. Res., Contr., vol. 4, pt. 2, pp. 31-35, pls. 4-7.

1930 – *Foraminifera of the Cisco group of Texas (exclusive of the Fusulinidae)*. Texas, Univ., Bull., no. 3019, pp. 22-81, pls. 2-12.

DEFRANCE, J. L. M.
1824 – *Minéralogie et géologie*. In: *Dictionnaire des Sciences Naturelles*. Paris: F. G. Levrault, vols. 30-31.

EHRENBERG, C. G.
1843 – *[Note of a communication on Polythalamia from the Mountain Limestone hornstone of Tula.]* K. Preuss. Akad. Wiss. Berlin, Ber., p. 79.

1854 – *Mikrogeologie*. Leipzig: L. Voss, pp. 1-374, pls. 1-40.

EICHWALD, E.
1860 – *Lethaea Rossica ou paléontologie de la Russie*. Stuttgart: E. Schweizerbart, vol. 1, pp. V-XIX, 1-681; Atlas, 1859, pls. 1-59.

EIMER, G. H. T., AND FICKERT, C.
1899 – *Die Artbildung und Verwandtschaft bei den Foraminiferen*. Zeitschr. Wiss. Zool., vol. 65, no. 4, pp. 599-708, tfs. 1-45.

GALLOWAY, J. J.
1933 – *A manual of foraminifera*. Bloomington, Indiana: Principia Press, pp. 1-480, pls. 1-42.

GALLOWAY, J. J., AND RYNIKER, C.
1930 – *Foraminifera from the Atoka formation of Oklahoma*. Oklahoma, Geol. Survey, Circ., no. 21, pp. 1-37, pls. 1-5.

GALLOWAY, J. J., AND SPOCK, L. E.
1933 – *Pennsylvanian foraminifera from Mongolia*. Amer. Mus. Nat. Hist., Novitates, no. 658, pp. 1-7, 1 pl.

GLAESSNER, M. F.
1945 – *Principles of micropalaeontology*. Melbourne: University Press, pp. vii-xvi, 3-296, pls. 1-14, tfs. 1-64, tables.

HARLTON, B. H.
1927 – *Some Pennsylvanian foraminifera of the Glenn formation of southern Oklahoma*. Jour. Pal., vol. 1, no. 1, pp. 15-27, pls. 1-5.

1928 – *Pennsylvanian foraminifera of Oklahoma and Texas*. Ibid., vol. 1, no. 4, pp. 305-310, pls. 52-53.

1933 – *Micropaleontology of the Pennsylvanian Johns Valley shale of the Ouachita Mountains, Oklahoma, and its relationship to the Mississippian Caney shale*. Ibid., vol. 7, pp. 3-29, pls. 1-7.

HUZIMOTO [FUJIMOTO], H.
1936 – *Stratigraphical and palaeontological studies of the Titibu System of the Kwantô-mountainland; Part 2 – Palaeontology.* Tokyo Bunrika Daig., Sci. Repts., sect. C, vol. 1, no. 2, pp. 29-125, pls. 1-26.

1938 – *Some foraminiferous fossils from the Kôten series of Zidô coalfield, Tyôsen.* Geol. Soc. Japan, Jour., vol. 45, no. 533, pp. 271-276, pl. 8.

JEPPS, M. W.
1942 – *Studies on Polystomella Lamarck.* Marine Biol. Assoc. United Kingdom, Jour., vol. 25, pp. 607-666, pls. 4-5, tfs. 1-10.

JONES, T. R.
1850 – *Foraminifera.* In: KING, W. A., *Monograph of the Permian fossils of England.* Palaeontogr. Soc. London, Monogr., pp. 15-20, table 6.

LANGE, E.
1925 – *Eine mittelpermische Fauna von Guguk Bulat (Padanger Oberland, Sumatra).* Geol.-Mijnb. Genoot. Nederland en Kol., Verh., Geol. Ser., vol. 7, pt. 3, pp. 213-295, pls. 1-5.

LEE, J. S.
1937 – *Foraminifera of the Donetz Basin and their stratigraphical significance.* Geol. Soc. China, Bull., vol. 16 (1936-1937), pp. 48-102, pls. 1-2, 1 tf.

LEE, J. S., CHEN, S., AND CHU, S.
1930 – *Huanglung limestone and its fauna.* Acad. Sinica, Nat. Res. Inst. Geol., Mem., no. 9, pp. 85-143, pls. 2-15.

LIEBUS, A.
1932 – *Die Foraminiferen.* In: *Die Fauna des deutschen Unterkarbons; Teil 3.* Preuss. Geol. Landesanst., Abh., new ser., no. 141, pp. 133-175, pls. 9-10.

LIPINA, O. A.
1948 – *Textulariidae in the upper part of the Lower Carboniferous of the southern flank of the Submoscovian Basin.* Akad. Nauk S.S.S.R., Inst. Geol. Nauk, Trudy, vol. 62 (Geol. Ser., no. 19), pp. 196-215.

MAJZON, L.
1943 – *Beiträge zur Kenntnis einiger Flysch-Schichten des Karpatenvorlandes mit besonderer Rücksicht auf die Globotruncanen.* Hungary, Magyar k. Földt. Int., Évk., vol. 37, no. 1, pp. 1-169, pls. 1-2.

MEUNIER, S.
1888 – *Examen paléontologique du calcaire à Saccammina de Cussy-en-Morven.* Soc. Hist. Nat. Autun, Bull., pp. 232-236, pl. 1.

MIKHAILOV, A.
1935*a* *Foraminifera from the Oka series of the Borovichi district.* [Russian with English summary.] Leningrad Geol., Hydrogeol., Geod. Trust, Bull., no. 2-3 (7-8), pp. 33-36.

1935*b* *On the question of the phylogeny of the Carboniferous foraminifera.* [Russian with English summary.] Leningrad Geol., Hydrogeol., Geod. Trust, Bull., no. 2-3 (7-8), pp. 38-42, 1 pl., tf. 1.

1939 – *To the characteristics of the genera of Lower Carboniferous foraminifera on the territory of the U.S.S.R.* In: MALIAVKIN, S. F. (ed.), *The Lower Carboniferous deposits of the north-western limb of Moscow Basin.* Leningrad, Geol. Admin., Symposium (Sborník), no. 3, pp. 47-62, pls. 1-4.

MILLER, A. K., AND CARMER, A. M.
1933 – *Devonian foraminifera from Iowa.* Jour. Pal., vol. 7, pp. 423-431, pl. 50.

(continued on page 242)

PLATE 1

1 Thin section of palaeotextulariid wall showing granular calcareous main element and inner "fibrous" layer; the latter has been recrystallised on the upper surfaces of the septa. × 55.

2 Thin section of palaeotextulariid wall showing granular calcareous main element partly recrystallised and giving "arenaceous" appearance; specimen set in a host sediment that has also undergone recrystallisation. × 50.

3 Thin section of palaeotextulariid wall showing linear arrangement of granules in the inner "fibrous" layer. × 120.

4 *Palaeotextularia angulata* Cummings, n. sp.
Holotype, × 33.

5 *Cribrostomum scoticum* Cummings, n. sp.
Holotype, × 44: a, obverse view; b, reverse view.

6 *Cribrostomum wilkiestoni* Cummings, n. sp.
Holotype, × 44.

7 *Cribrostomum ponielum* Cummings, n. sp.
Holotype, × 33.

8 *Cribrostomum inflatum* Cummings, n. sp.
Holotype, × 50: a, obverse view; b, reverse view.

9 *Cribrostomum linnum* Cummings, n. sp.
Holotype, × 45.

10 *Climacammina antiqua* (Brady)
Paratype, × 32.

11 *Climacammina antiqua* (Brady)
Paratype, thin section, × 27.

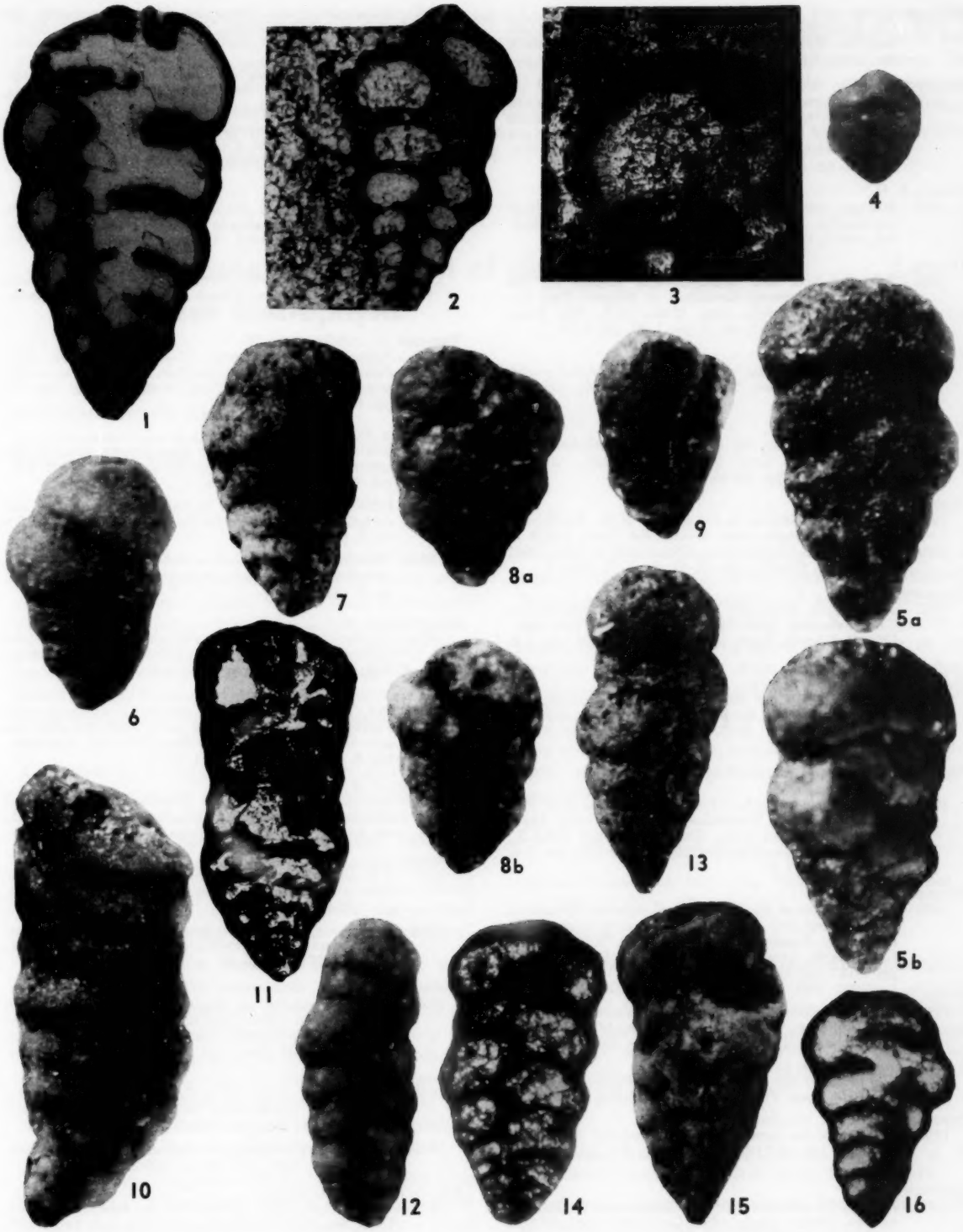
12 *Climacammina supraparva* Cummings, n. sp.
Holotype, × 50.

13 *Climacammina ferra* Cummings, n. sp.
Holotype, × 45.

14 *Climacammina ferra* Cummings, n. sp.
Paratype, thin section, × 45.

15 *Deckerella quadrata* Cummings, n. sp.
Holotype, × 33.

16 Thin section of palaeotextulariid wall showing recrystallisation of inner "fibrous" layer. × 50.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MÖLLER, V. VON
1879 – *Die Foraminiferen des russischen Kohlenkalks.* Acad. Imp. Sci. St.-Pétersbourg, Mém., ser. 7, vol. 27 (1880), no. 5, pp. 1-131, pls. 1-7, tfs. 1-30.

MOROZOVA, V. G.
1949 – *Representatives of the families Lituolidae and Textulariidae from the Upper Carboniferous and Artinskian deposits of the Bashkirian pre-Ural.* Akad. Nauk S.S.S.R., Inst. Geol. Nauk, Trudy, vol. 105 (Geol. Ser., no. 35), pp. 244-275, 5 pls.

MYERS, E. H.
1943 – *Biology, ecology, and morphogenesis of a pelagic foraminifer.* Stanford Univ., Publ., Univ. Ser., Biol. Sci., vol. 9, no. 1, pp. 1-30, 4 pls.

OZAWA, Y.
1925 – *Paleontological and stratigraphical studies on the Permo-Carboniferous limestone of Nagato; Part II – Paleontology.* Tokyo, Imp. Univ., Coll. Sci., Jour., vol. 45 (1923-1925), art. 6, pp. 1-90, pls. 1-14.

ORBIGNY, A. D. D'
1826 – *Tableau méthodique de la classe des céphalopodes.* Ann. Sci. Nat., ser. 1, vol. 7, pp. 96-169, 245-314, pls. 10-17.

PAALZOW, R.
1936 – *Die Foraminiferen im Zechstein des östlichen Thuringen.* Preuss. Geol. Landesanst., Jahrb., vol. 56 (1935), no. 1, pp. 26-45, pls. 3-5.

PLUMMER, H. J.
1945 – *Smaller foraminifera in the Marble Falls, Smithwick, and lower Strawn strata around the Llano Uplift in Texas.* Texas, Univ. (Bur. Econ. Geol.), Publ. 4401 (1944), pp. 209-271, pls. 15-17, tfs. 1-16, table 1.

POKORNÝ, V.
1953 – *The Middle Devonian foraminifera of Čelechovice, Czechoslovakia.* Král. Česká Spol. Nauk, Třida Mat.-Přírod., Věstník, Ročn. 1951, no. 9, pp. 1-29, pls. 1-2, tfs. 1-17.

RAUSER-CHERNOUSSOVA, D. M.
1936 – *Zur Frage von der stratigraphischen Bedeutung der Ober-Paläozoischen Foraminiferen.* Acad. Sci. U.S.S.R., Cl. Sci. Math. Nat., Bull., Ser. Géol., no. 1, pp. 61-86, tfs. 1-2.

RAUSER-CHERNOUSSOVA, D. M., BELJAEV, G. M., AND REITLINGER, E. A.
1936 – *Die oberpalaeozoischen Foraminiferen aus dem Petschora-Lande (der Westabhang des Nord-Urals).* Akad. Nauk S.S.S.R., Pol. Kom., Trudy [Acad. Sci. U.S.S.R., Polar Comm., Trans.], fasc. 28, pp. 159-232, pls. 1-6, tfs. 1-5, tables 1-5.

REITLINGER, E. A.
1950 – *[Foraminifera of the Middle Carboniferous formations of the central part of the Russian platform (exclusive of the family Fusulinidae).]* Akad. Nauk S.S.S.R., Inst. Geol. Nauk, Trudy, fasc. 126 (Geol. Ser., no. 47), pp. 1-127, pls. 1-22, tfs. 1-15, 1 table.

REUSS, A. E.
1862 – *Entwurf einer systematischen Zusammenstellung der Foraminiferen.* K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber., vol. 44 (1861), pt. 1, pp. 355-396.

ROTH, R., AND SKINNER, J.
1930 – *The fauna of the McCoy formation, Pennsylvanian, of Colorado.* Jour. Pal., vol. 4, pp. 332-352, pls. 28-31.

SCHELLWIEN, E.
1898 – *Die Fauna des karnischen Fusulinenkalks.* Palaeontographica, vol. 44 (1897-1898), fasc. 5-6, pp. 237-282, pls. 17-24.

SCHUBERT, R. J.
1907 – *Beiträge zu einer natürlicheren Systematik der Foraminiferen.* Neues Jahrb. Min. Geol. Pal., Beil.-Bd. 25 (1908), no. 1, pp. 233-260, tf. 1.

1920 – *Palaeontologische Daten zur Stammesgeschichte der Protozoen.* Pal. Zeitschr., vol. 3, no. 2, pp. 129-188.

SCHWAGER, C.
1865 – *Beitrag zur Kenntnis der mikroskopischen Fauna jurassischen Schichten.* Ver. Vaterl. Naturk. Württemberg, Jahreshefte, vol. 21, pp. 82-151, pls. 2-7.

1883 – *Carbonische Foraminiferen aus China und Japan.* In: RICHTOFEN, F. VON, *China.* Berlin: D. Reimer, vol. 4, Pal., art. 7, pp. 106-159, pls. 15-18.

SPANDEL, E.
1898 – *Die Foraminiferen des deutschen Zechsteins und ein zweifelhaftes mikroskopisches Fossil ebendaher.* Nuremberg: Verlags-Institut "General-Anzeiger," pp. 1-15, tfs. 1-11.

1901 – *Die Foraminiferen des Permo-Carbon von Hooser, Kansas, Nord Amerika.* Naturh. Ges. Nürnberg, Festschr. Saecular-Feier, pp. 177-194, tfs. 1-10.

TERMIER, G., AND TERMIER, H.
1950 – *Paléontologie marocaine; II – Invertébrés de l'Ere Primaire; Fasc. 1 – Foraminifères, spongiaires et coelentérés.* Morocco, Serv. Mines, Notes et Mém., no. 73, pp. 1-218, pls. 1-51.

THALMANN, H. E.
1949 – *Bibliography and index to new genera, species, and varieties of foraminifera for the year 1948.* Jour. Pal., vol. 23, no. 6, pp. 641-668.

1952*a* *Bibliography and index to new genera, species, and varieties of foraminifera for the year 1950.* Ibid., vol. 26, no. 2, pp. 223-268.

1952*b* *Bibliography and index to new genera, species, and varieties of foraminifera for the year 1951.* Ibid., vol. 26, no. 6, pp. 953-992.

TRAUTSCHOLD, H.
1879 – *Die Kalkbrüche von Mjatschkowa; Eine Monographie des oberen Bergkalks (Schluss).* Soc. Imp. Nat. Moscou, Nouv. Mém., vol. 14, pp. 3-82, pls. 1-7

VOLZ, W.
1904 – *Zur Geologie von Sumatra; Anhang II — Einige neue Foraminiferen und Korallen sowie Hydrokorallen aus dem Oberkarbon Sumatras.* Geol. Pal. Abh., new ser., vol. 6, no. 2, pp. 93-110, tfs. 26-45.

WARTHIN, A. S., JR.
1930 – *Micropaleontology of the Wetumka, Wewoka, and Holdenville formations.* Oklahoma, Geol. Survey, Bull., no. 53, pp. 1-94, pls. 1-7, charts.

WATERS, J. A.
1927 – *A group of foraminifera from the Dornick Hills formation of the Ardmore Basin.* Jour. Pal., vol. 1, no. 2, pp. 129-133, pl. 22.

1928 – *A group of foraminifera from the Canyon division of the Pennsylvanian formation in Texas.* Jour. Pal., vol. 1, no. 4, pp. 271-275, pl. 42.

WIESNER, H.
1931 – *Die Foraminiferen der deutschen Südpolar-Expedition 1901-1903.* In: DRYGALSKI, E. VON, *Deutsche Südpolar-Expedition 1901-1903.* Berlin and Leipzig: W. de Gruyter, vol. 20 (Zool., vol. 12), pp. 53-165, pls. 1-24.

WOOD, A.
1949*a* *The structure of the wall of the test in the foraminifera; its value in classification.* Geol. Soc. London, Quart. Jour., vol. 104, pt. 2, pp. 229-255, pls. 13-15.

1949*b* *The supposed Silurian foraminifera from Cardiganshire.* Geol. Assoc., Proc., vol. 60, pp. 226-228, pl. 8.

YOUNG, J., AND ARMSTRONG, J.
1871 – *On the Carboniferous fossils of the west of Scotland.* Geol. Soc. Glasgow, Trans., vol. 3, suppl., pp. 1-103, 1 table.

ABSTRACT: *In the last few years our knowledge of fossil Charophyta has rapidly increased. This is particularly due to the interest attached to their fructifications as important stratigraphic markers in Upper Silurian to late Tertiary strata. Data concerning fossil charophytes are scattered in botanical and geological publications. The lack of a comprehensive survey since Groves' review (1933) has placed many obstacles in the path of research in this field. The present paper is an attempt to summarize present-day knowledge of fossil charophyte genera with particular reference to nomenclatural status, typification, and synonymy. Brief diagnoses, records of numbers of species, and geologic distribution have been included.*

An annotated check-list of genera of fossil Charophyta

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Recent investigations of fossil charophytes have revealed that their generic taxonomy is far more intricate than had been realized. Several fossil charophyte taxa rest upon rather vague taxonomic and nomenclatural bases. Some organ-genera have scarcely been quoted or discussed since they were originally established, mainly because of uncertainty concerning their exact application. Other generic names have been used in a variety of ways.

A number of nomenclatural problems also arise in reviewing the names of fossil charophyte genera and organ-genera in the light of the present rules (International Code of Botanical Nomenclature, 1952). A detailed discussion of some of these names therefore seems to be necessary. In a few cases, nomenclatural changes unfortunately cannot be avoided, but in other instances retention of the established name is proposed.

Although the present check-list deals mainly with nomenclatural aspects, some data are also presented on the definition, number of species, and geologic distribution of each of the genera, as far as they are presently known. These notes have been included in order to increase the value of this list as a source of information. It should be noted however, that our rapidly increasing knowledge of the fossil Charophyta will make such a list out of date quite soon.

The following categories of generic names have been included: (1) Charophyte genera found exclusively in the fossil state; (2) genera of fossil plants or fossil animals that have been interpreted as charophytes or considered related to charophytes; (3) principally Recent genera of charophytes of which fossil representatives have been reported; (4) Recent genera of charophytes whose gyrogonites are difficult to distinguish with certainty from those of some fossil organ-genera; and (5) nomenclatural and taxonomic synonyms of the categories listed.

The present manuscript was completed on October 1, 1955, and consequently no subsequent changes have been included.

Genus **Acinaria** Rafinesque

Acinaria RAFINESQUE, 1819, Jour. Phys., Chimie, Hist. Nat. et Arts, vol. 89, p. 107.

Typification: None.

Reference: Nitella Agardh (a probable taxonomic synonym). Wood (1948, p. 283) considers this genus a probable synonym of *Nitella*, and, "if reinterpreted," with priority over the latter. The original application of *Acinaria* cannot be decided with certainty, however, and for that and other reasons, Wood relegates it to the *nomina inquirenda*.

Genus **Aclistochara** Peck

Aclistochara PECK, 1937, Jour. Pal., vol. 11, no. 2, p. 86; emend. MÄDLER, 1955, Geol. Jahrb., vol. 70, p. 271.

Typification: Aclistochara bransoni PECK, 1937, p. 87, pl. 14, figs. 8-11 (type of genus).

Aclistochara is an exclusively fossil organ-genus of gyrogonites. Between forty and fifty species represented in Pennsylvanian to Pliocene strata have been referred to it. A number of recent segregations (*Brachychara* and *Tectochara* of Grambast and Grambast, 1954*b*, pp. 665-671; *Latochara, Porochara,* and *Nodosochara* of Mädler, 1955, pp. 270-271, 276) have considerably restricted the number of species and geologic range of *Aclistochara s.str.* The type of the genus is Upper Jurassic (Morrison formation, United States). The generic diagnosis has been emended by Peck (1941, p. 290) and by Mädler (1955, p. 271). The latter redefines *Aclistochara* to comprise gyrogonites not having prolonged apical poles or dehiscence furrows. The apical spiral cell tips end, without any notable inflation, around comparatively large apical pores, closed by inner lids located below the pole surfaces.

Genus **Astrocharas** Stache

Astrocharas Stache, 1872, Austria, Geol. Reichsanst., Verh., no. 15, p. 316 *(nomen nudum).*

Astrochara Stache, 1880, ibid., no. 12, p. 201 *(nomen nudum)* (orthogr. var.).

Typification: None.

A name for some Paleocene stems with verticillate leaves; this name has two occasionally-used species epithets (Stache, 1880, p. 201), which are *nomina nuda. Astrocharas* was, but certainly without reason, ascribed by Stache to the Charophyta; it was redescribed by Edwards (1932, p. 213) as *Hippuridella stacheana* and considered related to the angiospermous Hippuridaceae. Being a *nomen nudum, Astrocharas* has, of course, no real nomenclatural status.

Genus **Atopochara** Peck

Atopochara Peck, 1938, Jour. Pal., vol. 12, no. 2, p. 173; emend. Peck, 1941, ibid., vol. 15, no. 3, p. 289.

Typification: Atopochara trivolvis Peck, 1938, p. 174, text-fig. 1; pl. 28, figs. 5-12 (type of genus).

An exclusively fossil organ-genus of utricles (probably also gyrogonites) comprising one Middle Cretaceous species of restricted vertical but fairly extended horizontal distribution.

Genus **Barrandeina** Stur

Barrandeina Stur, 1881, K. Akad. Wiss. Wien, Sitzber., vol. 84, pt. 1, p. 362.

Typification: Barrandeina Dusliana (Krejčí) Stur, 1881, p. 362, pl. 3, figs. 3-4; pl. 5, figs. 1-8 (type of genus) (*Protolepidodendron Duslianum* Krejčí, 1880, p. 203).

Although placed by Stur in the "Characeae praecursiores," this Devonian genus has no affinity with the Charophyta. The systematic position of the generic type is somewhat doubtful; it has been alternatively placed among the Lycopodiales *incertae sedis* or among the Psilophytales (see Kräusel and Weyland, 1933, p. 18; Jongmans, 1936, pp. 1005-1006).

Genus **Bechera** Sternberg

Bechera Sternberg, 1825, Vers. geogn-bot. Darst. Fl. Vorw., vol. 1, fasc. 4, p. xxx, pl. 19, fig. 3; pl. 31, fig. 4; pl. 35, fig. 3; pl. 49, figs. 1-2; pl. 51, fig. 3; pl. 55, figs. 3, 5.

Typification: None.

Bechera was established to comprise a number of heterogeneous fossil plant remains with articulated primary and verticillate secondary axes. These may possibly include some vegatative remains of fossil charophytes, but this is difficult to decide; Sternberg, however, also included three species of charophyte gyrogonites previously described as *Chara* Linnaeus and *Gyrogonites* Lamarck.

Genus **Brachychara** Grambast and Grambast

Brachychara Grambast and Grambast, 1954, Rev. Gén. Bot., vol. 61, p. 666.

Typification: Brachychara medicaginula (Lamarck) Grambast and Grambast, 1954*b*, p. 666 (type of genus) (*Gyrogonites medicaginula* Lamarck, 1822, p. 614).

Grambast and Grambast typified their new genus *Brachychara* by *Brachychara medicaginula,* which is nomenclaturally the same as *Gyrogonites medicaginula* Lamarck, the type of the genus *Gyrogonites.* Being typified by the same species, these genera are nomenclatural synonyms, the older one of which has priority. The valid name of this principally Lower Tertiary organ-genus of charophyte gyrogonites is thus *Gyrogonites* Lamarck, and the name *Brachychara* should be considered illegitimate, having been nomenclaturally superfluous when published (Int. Code Bot. Nom., Art. 73:1).

Mädler (1955, pp. 267-268) has shown, however, that Lamarck's description and figure of *Gyrogonites medicaginula* permit no detailed comparison with the charophyte organ-genera now recognized, and that the original material of *Gyrogonites medicaginula* probably included gyrogonites of *Sphaerochara* Mädler. The original meaning of the name *Gyrogonites medicaginula* is, accordingly, obscure.

Grambast and Grambast (1953, p. 290) identified some gyrogonites among the Paris Basin Charophyta with the *Gyrogonites medicaginula* of Lamarck, and transferred the latter to *Aclistochara* as *Aclistochara medicaginula.* Later, in segregating *Brachychara* from *Aclistochara,* Grambast and Grambast (1954*b*, p. 666) used *Aclistochara medicaginula* to typify the former organ-genus, but it seems rather difficult to prove that *Brachychara medicaginula sensu* Grambast and Grambast is identical with the *Gyrogonites medicaginula* of Lamarck. The exact application of the latter name is unknown, as noted above.

Some puzzling implications emerge out of this situation: (1) *Brachychara* is an illegitimate name and a nomenclatural synonym of *Gyrogonites;* (2) the exact application of the name *Gyrogonites* is unknown, and, accordingly, cannot be used for the *Brachychara* gyrogonites; (3) it seems difficult to prove that *Gyrogonites medicaginula* of Lamarck and *Brachychara medicaginula* of Grambast and Grambast represent the same species of gyrogonite, and accordingly, *Gyrogonites* and *Brachychara,* although nomenclatural synonyms, may not be taxonomic synonyms. The gyrogonites designated *Brachychara* cannot bear either that name or the earlier name *Gyrogonites.* Since, for the time being, it appears useful to distinguish these forms from typical *Tectochara* gyrogonites, to which they are, however, connected by transitional forms, they should be renamed and retypified. The present writer proposes the name *Brevichara* as the designation of this genus. In principle, therefore, *Brevichara* is a new name for *Brachychara,* but some alterations of the original diagnosis are suggested, in order to exclude tuberculated gyrogonites.

Genus **Brevichara** Horn af Rantzien, **new name**

Brachychara Grambast and Grambast, 1954, Rev. Gén. Bot., vol. 61, p. 666 *(pro parte, exclus. typ. gen. et formae tuberc.).*

Typification: Brevichara hordlensis Horn af Rantzien, new name (type of genus) *(Chara Wrightii* Reid and Groves, 1921, p. 183, pl. 4, fig. 1; *Aclistochara wrightii* Grambast and Grambast, 1954*a*, p. 95, text-fig. 1; *Brachychara wrightii* Grambast and Grambast, 1954*b*, p. 667; *non Chara wrightii* Salter in Forbes, 1856, p. 160, pl. 7, figs. 15-21).

Diagnosis: Organ-genus represented by gyrogonites with five sinistrally spiralled non-tuberculated enveloping cells. Apical pole with a marked peripheral dehiscence furrow caused by interrupted calcification of the spiral cells. Tips of the apical spiral cells not notably narrower in the dehiscence furrow, but more or less inflated terminally, forming an apical hood or rosette which is often slightly sunken into the apical pole, separated from its periphery by more or less wide, even spaces. When the apical hood is broken away, the ends of the interrupted spiral cells are more or less obtuse.

The reasons for the present renaming and retypification have been discussed under *Brachychara* Grambast and Grambast and *Gyrogonites* Lamarck. So far, only a few Paleocene to Oligocene species are known to belong to this genus.

Genus **Calcisphaera** Williamson

Calcisphaera Williamson, 1880, Roy. Soc. London, Philos. Trans., vol. 171, no. 14, p. 520.

Typification: Calcisphaera robusta Williamson, 1880, p. 523, pl. 20, fig. 81 (lectotype of genus, Miller, 1889, p. 155; since this lecto-typification implies grave nomenclatural inconveniences, the writer would suggest that Miller's choice be rejected).

Reference: Trochiliscus Karpinsky (as lectotypified by Miller, an earlier taxonomic synonym of this name).

Calcisphaera was established by Williamson (loc. cit.) for doubtful organisms from the Carboniferous of Wales with suggested affinity to radiolarians. A few charophyte gyrogonites from the North American Devonian, of whose nature Williamson was unaware, were compared with the Carboniferous fossils and with some hesitation referred to *Calcisphaera* as *Calcisphaera robusta.* Williamson chose no generic type. Since the discussion was restricted mainly to the Carboniferous remains, Miller's proposal to typify *Calcisphaera* by *Calcisphaera robusta* was somewhat unfortunate, for the name *Calcisphaera* was apparently applied to Carboniferous fossils of supposed radiolarian nature. The charophyte gyrogonites were redescribed by Karpinsky (1906, p. 123) as *Trochiliscus robustus.* The taxonomic synonymy of *Calcisphaera robusta* and *Trochiliscus* is clear, but no one has suggested that the latter is synonymous with the Carboniferous remains referred to *Calcisphaera.* However, as lectotypified by *Calcisphaera robusta, Calcisphaera* has priority over *Trochiliscus,* although it was relegated to synonymy with the latter by Peck (1934*b*, p. 105). If the established name *Trochiliscus* is to be retained, it will have to be protected from the priority of *Calcisphaera.* Perhaps a simpler procedure is to cancel Miller's lectotype, a practice permitted by Article 19 of the International Code of Botanical Nomenclature.

Genus **Chara** Linnaeus

Chara (Vaillant *ex*) Linnaeus, 1753, Sp. plant., ed. 1, vol. 1, p. 1156; Linnaeus, 1754, Gen. plant., ed. 5, p. 491 (descr.); emend. Braun in Braun and Nordstedt, 1883, K. Akad. Wiss. Berlin, Abh., Jahrg. 1882, p. 105.
Characias Rafinesque, 1815, p. 209 (taxonomic synonym).
Charopsis Kützing, 1843, p. 319 (*pro parte*) (taxonomic synonym).

Typification: Chara tomentosa Linnaeus, 1753, p. 1156 (lectotype of genus, Horn af Rantzien and Olsen, 1949, p. 99).

In its original sense a common designation of all Characeae, *Chara* has later been used in a rather more restricted sense as the name of a Recent genus. Gyrogonites of fossil charophytes were first included in this genus by Brongniart (1822, pp. 320-322). As an organ-genus of gyrogonites, *Chara* has been used to cover a rather heterogeneous array of forms, about 160 species having been referred to it. *Chara* has, moreover, been construed as a form-genus of vegetative remains interpreted as fossil charophytes. There are, in all, about 170 fossil species of gyrogonites and thallus fragments; for comparison it may be mentioned that there are about 120 recognized Recent species of *Chara.* Pia (1927, pp. 89-90) removed the gyrogonites and other fossil charophyte remains to various

organ-genera and form-genera (*Gyrogonites* Lamarck, *Kosmogyra* Stache, *Kosmogyrella* Stache, *Characeites* Pia *non* Tuzson). Since 1937, several other organ-genera of fossil Charophyta have been established on the basis of their gyrogonite morphology. As a fossil organ-genus, *Chara* is at present mainly used to designate the gyrogonite residue that has not been transferred to other fossil organ-genera. Inasmuch as few gyrogonites of that residue can possibly be identified with the female gametangia or fructifications of present-day *Chara*, this practice can hardly be deemed justifiable (Horn af Rantzien, 1954*b*, pp. 2-3). In fact, we know only one indubitable pre-Quaternary species of *Chara*, the Eocene species *Chara sausari* Sahni and Rao (1943, p. 215). The two Oligocene and Miocene species referred to *Chara* by Mädler (1955, pp. 306-307) also probably belong here.

In this connection it should be remembered, however, that it is difficult to distinguish with absolute certainty female gametangia and fructifications of the Recent genera *Chara* Linnaeus and *Lamprothamnium* Groves, and that fossil gyrogonites referred to *Chara* may belong equally well to one or to the other. They are closely related, and there are good reasons for uniting them in one genus.

In the paleontologic literature, Vaillant is often quoted as the *auctor* of the name Chara. According to the International Code of Botanical Nomenclature, the nomenclatural starting-point of this group is 1753, and Linnaeus is, accordingly, the formal author.

Genus **Characeites** Tuzson

Characeites Tuzson, 1914, Hungary, K. Ungar. Geol. Reichanst., Mitt. Jahrb., vol. 21, no. 8, p. 233, pl. 13, figs. 1-3; *non* Pia in Hirmer, 1927, Handb. Paläobot., vol. 1, p. 89.

Typification: None.

An organ-genus established to include fossil gyrogonites not definitely referable to any Recent charophyte genus. *Characeites* was based on three species, of which one is a tuberculated form and the others are of even more uncertain affinity. Since Tuzson's original material appears to have been lost, the original application of the name *Characeites* will remain doubtful. It should therefore be disposed of as a *nomen inquirendum*. Since, moreover, the original material was apparently heterogeneous, the name is illegitimate and cannot be re-interpreted as a designation of gyrogonites of uncertain affinity.

Genus **Characeites** Pia

Characeites Pia in Hirmer, 1927, Handb. Paläobot., vol. 1, p. 89; *non* Tuzson, 1914, Hungary, K. Ungar. Geol. Reichsanst., Mitt. Jahrb., vol. 21, no. 8, p. 233, pl. 13, figs. 1-3.

Typification: None.

Homonymy: A later illegitimate homonym of *Characeites* Tuzson.

Reference: Charaxis Harris (an earlier taxonomic synonym of this name).

Tuzson's *Characeites* (an organ-genus of gyrogonites) was illegitimately emended by Pia to comprise Tertiary vegetative corticated Characeae remains. The original members of Tuzson's organ-genus were removed to *Gyrogonites* Lamarck and to *Kosmogyra* Stache.

Genus **Characias** Rafinesque

Characias Rafinesque, 1815, Anal. Nat., p. 209 *(nomen nudum)*; Rafinesque, 1836, Fl. Tellur., vol. 1, p. 56 *(nomen nudum)*.

Typification: None.

Reference: Chara Linnaeus (a probable later taxonomic synonym, according to Wood, 1948, p. 282).

Genus **Charaxis** Harris

Charaxis Harris, 1939, Brit. Purb. Char., p. 67.
Characeites Pia, 1927, p. 89 (*non* Tuzson, 1914, p. 233).

Typification: None.

The typification of organ-genera and form-genera of fossil plants is still a disputed question. It has been referred to a paleobotanical nomenclature committee for the preparation of proposals to the next International Botanical Congress. With respect to this particular case, Harris (loc. cit.) wrote: "As this is probably an artificial genus, it would be meaningless to select a type-species." The best known species is *Charaxis durlstonense* Harris (op. cit., p. 67, text-figs. 14-15, pl. 16, fig. 10) from the British Purbeck; if necessary, this might be chosen as a future lectotype. With regard to the taxonomic position of *Charaxis*, Harris (loc. cit.) says: "In the absence of evidence to the contrary, it is presumed that this genus belongs to the Characeae in the strict sense, but it would not be surprising if some of the species proved on closer knowledge to be widely different."

Charaxis Harris is the valid name for vegetative corticated remains of fossil charophytes corresponding (insofar as they are known) with Recent *Chara*.

Genus **Charina** Filarszky

Charina Filarszky and G. O. Allen *ex* Filarszky, 1937, Magyar Tudom. Akad., Math.-Termés. Értes., vol. 55, p. 490.

Typification: Charina verticillata Filarszky and G. O. Allen *ex* Filarszky, 1937, p. 490 (type of genus).

Reference: Nitella Agardh (a taxonomic synonym).

Although the material on which Filarszky based his diagnosis has not been re-examined recently, all the available evidence points to its being a species of *Nitella* (see Wood, 1952, p. 330). The name *Charina* should therefore doubtless be reduced to a synonym of *Nitella*.

Genus **Charopsis** Kützing

Charopsis Kützing, 1843, Phycol. gen., p. 319.

Typification: None.

References: Chara Linnaeus and *Lychnothamnus* (Meyen) von Leonhardi (a taxonomic synonym of both).

This genus was based on three species, of which two were later included in *Chara* and the third was chosen as the lectotype of *Lychnothamnus*. Of the two synonyms, *Chara* (1753) is older and *Lychnothamnus* (1863) is younger than *Charopsis*. Since the latter was never typified, and was, moreover, based upon heterogeneous material, there is no need to reject *Lychnothamnus* in favor of *Charopsis*.

Genus **Clavator** Reid and Groves

Clavator Reid and Groves, 1916, Roy. Soc. London, Proc., ser. B, vol. 89, p. 253, pl. 8 *(descr. et fig. generis);* Groves, 1924, Jour. Bot., vol. 62, p. 116 *(typif.);* emend. Harris, 1939, Brit. Purb. Char., p. 14.

Typification: Clavator Reidii Groves, 1924, p. 116 (lectotype of genus).

Unlike most genera of exclusively fossil Charophyta, *Clavator* comprises specimens with both reproductive and vegetative organs. Of the five species known (Kimmeridgian and Purbeckian of Europe, Lower Cretaceous of the Rocky Mountains), the Swiss and British Purbeckian are the best preserved, the others being mainly represented by gyrogonites and utricles.

With regard to the typification, *Clavator* was described under its generic name in 1916, but without any specific epithet. In 1924, only the species name was published, but reference was made to the generic diagnosis of 1916. *C. Reidii* is, accordingly, the lectotype of the genus, designated by the author himself (Int. Code Bot. Nom., Art. 18, Note 3: "A lectotype is a specimen . . . selected . . . as nomenclatural type when the holotype was not designated at the time of publication"). Harris (1939, p. 16) points out: "The way in which the name *C. reidi* was bestowed is somewhat irregular, but there is no doubt to what fossil it applies."

Genus **Clavatorites** Horn af Rantzien

Clavatorites Horn af Rantzien, 1954, Opera Bot., vol. 1, no. 2, p. 47.

Typification: Clavatorites höllvicensis Horn af Rantzien, 1954*a*, p. 48, pl. 4, fig. 4 (type of genus).

This organ-genus was established to include gyrogonites with features characteristic of the Clavatoraceae which, because of the absence of utricles and vegetative remains, cannot be referred to any of the genera of this family. One species is reported from the Middle Triassic.

Genus **Cristatella** (Stache) Groves

Cristatella (Stache) Groves, 1933, Foss. Cat., II, fasc. 19, p. 39.

Nitella, (?)subgenus *Cristatella* Stache, 1889, Austria, Geol. Reichsanst., Abh., vol. 13, no. 1, pp. 131, 136.

Typification: Cristatella doliolum Stache, 1889, p. 136, pl. 4, fig. 8 (type of genus).

As it has subsequently been considered to be based on insignificant morphological characters, *Cristatella,* a Paleocene organ-genus of gyrogonites, has been rejected (Mädler, 1952, p. 6). The generic type has not been re-examined, however, and a decision as to its taxonomic position based on the only illustration published (Stache, op. cit., pl. 4, fig. 8) (rather generalized) appears difficult. *Cristatella* is certainly not worth retaining, but as it has not been formally reduced to a synonym of any other organ-genus, it is still listed here as recognized.

Genus **Favreina** Bronnimann

Favreina Bronnimann, 1955, Micropaleontology, vol. 1, no. 1, p. 40.

Typification: Favreina joukowskyi Bronnimann, 1955, p. 40, text-fig. 5e-n, pl. 2, fig. 11 (type of genus).

Favreina is a form-genus of problematic fossils distributed from the Infra-Lias to the upper Aptian of Switzerland, France and Cuba. Cuvillier (1951) suggests that the same fossils (undescribed) are related to the Charophyta, but Bronnimann (loc. cit.) does not think this very likely. Judging by the descriptions and illustrations published, there is certainly no reason to believe that *Favreina* represents vegetative remains of fossil charophytes.

Genus **Gyrogona** Lamarck

Gyrogona (Lamarck *ex*) Lamarck, 1822, Hist. Nat. Anim. s. Vert., vol. 7, p. 613 (Lamarck, 1804, Paris, Mus. National Hist. Nat., Ann., vol. 5, p. 355).

Typification: Although not formally typified, *Gyrogona* was apparently meant to be typified by *Gyrogonites medicaginula* Lamarck, 1822, p. 614.

Reference: Gyrogonites Lamarck (a nomenclatural(?) synonym).

Genus **Gyrogonites** Lamarck

Gyrogonites (Lamarck *ex*) Lamarck, 1822, Hist. Nat. Anim. s. Vert., vol. 7, p. 614 (Lamarck, 1804, Paris, Mus. National Hist. Nat., Ann., vol. 5, p. 356).
Gyrogona (Lamarck, 1804, p. 355 *ex*) Lamarck, 1822, p. 613.
Brachychara Grambast and Grambast, 1954*b*, p. 666.

Typification: Gyrogonites medicaginula (Lamarck, 1804, p. 356 (descr.); Lamarck, 1807, pl. 17, fig. 7 (fig.), *ex*) Lamarck, 1822, p. 614 (type of genus).

The somewhat intricate nomenclatural problems associated with the generic names *Gyrogona* and *Gyrogonites* have already been discussed in part under *Brachychara*. Lamarck's publication of *Gyrogona* and *Gyrogonites* in 1804 would have been legitimate if the nomenclatural starting-point of all groups of fossil plants had not been fixed at December 31, 1820 (as adopted by the Eighth International Botanical Congress, in Paris, 1954; see Taxon, 1955, vol. 4, no. 7, p. 163). The first publications of these names after that date are, accordingly, the valid ones.

With regard to their linguistic forms, Lamarck (1804, p. 355) used the generic name *Gyrogona*, accompanied by a Latin diagnosis, but typified the genus on the following page by the only species included in it, *Gyrogonites medicaginula*. When these names were validly published (Lamarck, 1822, pp. 613-614), the same designations were used, that is, *Gyrogona* for the genus and *Gyrogonites* for the generic type. If a choice between these names must be made, the latter should, logically, be preferred because of the indissoluble attachment of the generic name to its generic type, nomenclaturally the basic element. However, it is possible to hold a different view, and in this particular case, conditions may permit us to choose either name.

Mädler (1955, pp. 267-268) has pointed out that the type material of *Gyrogonites medicaginula* may have included different kinds of gyrogonites, one of which was referable to *Sphaerochara*. It is, moreover, rather apparent that the description and figures of *Gyrogonites medicaginula* supplied by Lamarck are too generalized to permit a detailed comparison with the charophyte organ-genera now recognized. The meaning and application of the name *Gyrogonites medicaginula*, and accordingly also of the generic names *Gyrogonites* and *Gyrogona*, are for that reason obscure.

Nevertheless, a great many gyrogonites of fairly different kinds have been referred to this genus or quoted as this species, and they have accordingly been persistent sources of confusion. Since *Gyrogonites medicaginula* was included in the genus *Chara* by Brongniart (1822, pp. 320-322), the name *Gyrogonites* was not used much for about a century. But in 1927 it was revived by Pia, although with rather wide limits so as to comprise most fossil non-tuberculated charophyte gyrogonites not referable to Recent genera. The majority of authorities, including Peck (1941, p. 289), Rásky (1945, p. 29), and Mädler (1952, p. 3), have not accepted Pia's proposal, however, although it was supported by Croft (1952, p. 214), principally because of the uncertain original application of the name.

As noted elsewhere, Grambast and Grambast (1954*b*, p. 666) used *Gyrogonites medicaginula* as the type of the organ-genus *Brachychara*. This made *Gyrogonites* and *Brachychara* nomenclatural, although not necessarily taxonomic, synonyms inasmuch as the identity of Lamarck's *Gyrogonites medicaginula* with the gyrogonite species by which Grambast and Grambast typified *Brachychara* has not been proved.

At least one of the negative stipulations in the present International Code of Botanical Nomenclature seems to be directly applicable to the name *Gyrogonites:* Article 75 states: "A name of a taxon must be rejected if it is used with different meanings, and so becomes a long-persistent source of error."

To avoid this nomenclatural confusion, the writer would suggest: (1) That the names *Gyrogonites* and *Gyrogona* be rejected as *nomina confusa rejicienda* since they cannot be re-interpreted with any certainty and since the negative requirements of Article 75 are definitely applicable to them; (2) that the name *Brachychara* be listed as a nomenclatural synonym of the rejected genus *Gyrogonites;* and (3) that the major part of the gyrogonite assemblage designated *Brachychara* be given a new name, *Brevichara,* typified by another species of the same morphological group.

Genus **Kosmogyra** Stache

Kosmogyra STACHE, 1889, Austria, Geol. Reichsanst., Abh., vol. 13, no. 1, p. 134.

Typification: Kosmogyra superba STACHE, 1889, p. 134, pl. 4, fig. 2 (lectotype of genus, MÄDLER, 1955, p. 302).

An exclusively fossil (Paleocene to Pliocene) organ-genus of charophyte gyrogonites with cellular tubercles, characterized by the absence of apical dehiscence furrows and inflated spiral cell tips. More than twenty species have been described, but quite a few of them may, on re-examination, prove to belong to other tuberculated organ-genera.

Genus **Kosmogyrella** Stache

Kosmogyrella STACHE, 1889, Austria, Geol. Reichsanst., Abh., vol. 13, no. 1, p. 121.

Typification: Kosmogyrella carinata STACHE, 1889, p. 121, pl. 2, fig. 19 (type of genus).

A Paleocene and Eocene gyrogonite organ-genus comprising one or, according to Pia (1927, p. 90), two species. *Kosmogyrella* has been considered insufficiently distinct taxonomically and morphologically (Mädler, 1952, p. 6), but as it has not been relegated to synonymy with any other organ-genus (it can hardly be re-interpreted on the basis of the vague description and schematic illustration), it is listed here as recognized. It is not quite clear, from Stache's treatment of this group, whether he intended to give *Kosmogyrella* the rank of an independent genus or that of a subgenus of *Kosmogyra* Stache.

Genus **Kosmogyrina** Mädler

Kosmogyrina MÄDLER, 1952, Geol. Jahrb., vol. 67, p. 6.

Typification: Kosmogyrina andreanszkyi (RÁSKY) MÄDLER, 1952, p. 6 (type of genus) *(Chara andreanszkyi* RÁSKY, 1945, p. 37, pl. 1, figs. 19-21).

An Oligocene gyrogonite organ-genus characterized by the presence of intercellular tubercles and the absence of apical dehiscence furrows. Only one species known.

Genus **Lagynophora** Stache

Lagynophora STACHE, 1880, Austria, Geol. Reichsanst., Verh., no. 12, pp. 198-199; STACHE, 1889, Austria, Geol. Reichsanst., Abh., vol. 13, no. 1, p. 132.

Typification: Lagynophora liburnica STACHE, 1880, pp. 198-199; STACHE, 1889, p. 132, pl. 4, fig. 9 (type of genus).

Lagynophora comprises five Paleocene species represented by specimens with both vegetative and reproductive organs. The genus has been made the type of a family, the Lagynophoraceae.

Genus **Lamprothamnium** Groves

Lamprothamnium GROVES, 1916, Jour. Bot., vol. 54, p. 337.
Lamprothamnus BRAUN in BRAUN AND NORDSTEDT, 1883, p. 100 (*non* HIERN, 1877, Fl. Trop. Afr., vol. 3, p. 130).

Typification: Lamprothamnium papulosum (WALLROTH) GROVES, 1916, p. 337 (type of genus) (*Chara papulosa* WALLROTH, 1833, p. 107).

Lamprothamnium is a Recent genus of Characeae allied to *Chara* Linnaeus (the taxonomic differences between the two are comparatively small) and comprising one or a few species. It has not yet been found in the fossil state, but the close similarity of its female gametangia and fructifications to those of *Chara* imply that fossil gyrogonites referred to *Chara s.str.* might well represent *Lamprothamnium*.

Genus **Lamprothamnus** Braun

Lamprothamnus BRAUN in BRAUN AND NORDSTEDT, 1883, K. Akad. Wiss. Berlin, Abh., Jahrg. 1882, p. 100 (*non* HIERN, 1877, Fl. Trop. Afr., vol. 3, p. 130).

Typification: Lamprothamnus alopecuroides (WALLMAN) BRAUN in BRAUN AND NORDSTEDT, 1883, p. 100 (type of genus) (*Chara alopecuroides* WALLMAN, 1853, p. 53).

Homonymy: A later illegitimate homonym of *Lamprothamnus* Hiern.

Reference: Lamprothamnium Groves (a taxonomic synonym).

Genus **Latochara** Mädler

Latochara MÄDLER, 1955, Geol. Jahrb., vol. 70, p. 271.

Typification: Latochara latitruncata (PECK) MÄDLER, 1955, p. 271 (type of genus) (*Aclistochara latitruncata* PECK, 1937, p. 89, pl. 14, figs. 1-4).

A Jurassic organ-genus of hemispherical or urn-shaped gyrogonites characterized by apical centres fortified by strong ridges of which the peak-shaped prolongations extend above the surfaces of the apical poles; by dehiscence furrows; and by spiral cells lacking decoration.

Genus **Leiacina** Rafinesque

Leiacina RAFINESQUE, 1825, Neogenyton, p. 4.

Typification: Leiacina capitata RAFINESQUE, 1825, p. 4 (type of genus) (= *Nitella capitellata* BRAUN in BRAUN AND NORDSTEDT, 1883, p. 56, *fide* WOOD, 1948, p. 283).

Reference: Nitella Agardh (typified as above, a later taxonomic synonym).

Wood (loc. cit.) considers this generic name typified as stated above and accordingly synonymous *"pro synon."* with *Nitella* Agardh, but *"pro descr."* probably identical with *Tolypella* (Braun) von Leonhardi, and, if so re-interpreted, with priority over the latter name. However, since it cannot be re-interpreted with certainty, and since it is, moreover, a later homonym, according to Wood, *Leiacina* is illegitimate.

Genus **Leonardosia** Sommer

Leonardosia SOMMER, 1955, Paleontologia do Paraná, 1954, pp. 175-194.

Typification: Leonardosia langei SOMMER, 1955 (type of genus).

The existence of this organ-genus was reported by Lange (1954, p. 11). Dr. F. W. Sommer has kindly informed me that a description has been published in Paleontologia do Paraná, 1954, pp. 175-194. This was printed December 19, 1954, but no copies of the volume or reprints have been distributed. The type species is represented by Permian impressions of gyrogonites.

Genus **Lychnothamnus** (Ruprecht) von Leonhardi

Lychnothamnus (RUPRECHT) VON LEONHARDI, 1863, Lotos, vol. 13, p. 72.
Chara, subgenus *Lychnothamnus* RUPRECHT, 1845, p. 80 *(pro parte)*.
Charopsis KÜTZING, 1843, p. 319 *(pro parte)*.

Typification: Lychnothamnus barbatus (MEYEN) VON LEONHARDI, 1863*a*, p. 57 (lectotype of genus, GROVES, 1919, p. 128: ". . . *L. barbatus*, which must be regarded as the type of the genus") (*Chara barbata* MEYEN, 1827, p. 75, pl. 3, figs. 7-8).

Although the Recent monotypic genus *Lychnothamnus* is not yet known to occur in the fossil state, some Tertiary gyrogonites may, according to recent unpublished investigations, represent this or allied forms. The genus is sometimes considered to have been typified by von Leonhardi (op. cit., p. 57) by a casual reference to *Lychnothamnus barbatus*, but this is not true.

Genus **Macropogon** Migula

Macropogon Migula, 1897, Char. Deutschl., Oesterr., Schw., p. 273.

Typification: Macropogon australicum Migula, 1897, p. 273 (type of genus).

Reference: The taxonomic position of the generic type has been variously interpreted, and, as a result, *Macropogon* has been considered to be a taxonomic synonym of *Chara* Linnaeus, of *Lamprothamnium* Groves, and of *Lychnothamnus* (Ruprecht) von Leonhardi.

Genus **Moellerina** Ulrich

Moellerina Ulrich, 1886, Contr. Amer. Pal., vol. 1, p. 34.

Typification: Moellerina Greenei Ulrich, 1886, p. 35, pl. 3, fig. 8 (type of genus).

Reference: Trochiliscus Karpinsky (a probable earlier taxonomic synonym, but difficult to re-interpret with certainty).

The fossils designated as *Moellerina greenei* were thought to be foraminifera, and were obtained from the Devonian Jeffersonville limestone at the Falls of the Ohio, Louisville, Kentucky. Similar fossils from the same locality, representing an identical or allied taxon, were redescribed by Knowlton (1889, p. 209) as *Calcisphaera lemoni;* they were considered problematical forms by that author. Karpinsky (1906, pp. 113-115) found that Knowlton's material represented gyrogonites of trochilisks, and referred them to *Trochiliscus* as *Trochiliscus lemoni.* There is, accordingly, some reason to think that *Moellerina* may be congeneric with *Trochiliscus,* but the vague description and unsatisfactory illustrations make this difficult to prove in the absence of definitely authentic material.

Genus **Nannoconus** Kamptner

Nannoconus Kamptner, 1931, Pal. Zeitschr., vol. 13, no. 4, p. 288.

Typification: Nannoconus steinmanni Kamptner, 1931, p. 288, text-figs. 2-3 (type of genus).

Nannoconus is a fossil form-genus of doubtful taxonomic position found in the uppermost Jurassic to Lower Cretaceous of southern Europe and Cuba. It has recently been restudied by Bronnimann (1955, pp. 28-39), who compares *Nannoconus* tests with charophyte gyrogonites, although without suggesting any close affinity. In spite of some points of external resemblance, Bronnimann's instructive illustrations do not support the idea of affinity between the two groups.

Genus **Nitella** Agardh

Nitella Agardh, 1824, Syst. Alg., p. xxvii; emend. von Leonhardi, 1863, Lotos, vol. 13, p. 69.
Acinaria Rafinesque, 1819, p. 107 (probable taxonomic synonym).
Charina Filarszky and G. O. Allen *ex* Filarszky, 1937, p. 490 (probable taxonomic synonym).
Leiacina Rafinesque, 1825, p. 4 (probable taxonomic synonym).

Typification: Nitella opaca Agardh, 1824, p. 124 (lectotype of genus, Horn af Rantzien and Olsen, 1949, p. 99).

A Recent genus comprising about 150 recognized species. A few Cretaceous and later gyrogonites have been referred to *Nitella,* but except for occasional Quaternary specimens they are not referable to this genus but belong to various fossil organ-genera.

Genus **Nitellopsis** Hy

Nitellopsis Hy, 1889, Soc. Bot. France, Bull., vol. 36, p. 398.
Tolypellopsis (von Leonhardi) Migula, 1897, p. 253 (taxonomic synonym).
Chara, subgenus *Tolypellopsis* von Leonhardi, 1863*a*, p. 73 (taxonomic synonym).

Typification: Nitellopsis stelligera (Reichenbach) Hy, 1890, p. 46 (lectotype of genus, chosen by the *auctor*) (*Chara stelligera* Reichenbach, 1829, p. 1595).

A Recent genus comprising one or two closely allied species. Gyrogonites of a type resembling fructifications of *Nitellopsis* have been encountered in late Neogene deposits.

Genus **Nodosochara** Mädler

Nodosochara Mädler, 1955, Geol. Jahrb., vol. 70, p. 276.

Typification: Nodosochara clivulata (Peck and Reker) Mädler, 1955, p. 276 (type of genus) (*Aclistochara clivulata* Peck and Reker, 1948, p. 88, pl. 21, figs. 1-7).

An exclusively fossil organ-genus comprising gyrogonites, the apical morphology of which corresponds to *Tectochara,* but which are provided with cellular tubercles corresponding to those of *Kosmogyra.* The type species is of Eocene age.

Genus **Obtusochara** Mädler

Obtusochara Mädler, 1952, Geol. Jahrb., vol. 67, p. 36.

Typification: Obtusochara prima Mädler, 1952, p. 36, pl. B, figs. 53-55 (type of genus).

A Jurassic organ-genus, defined as including gyrogonites that are apically flattened but lack dehiscence furrows or inflations of their apical spiral cell tips. Only the type species has been referred to this genus.

Genus **Palaeochara** Bell

Palaeochara Bell, 1922, Roy. Soc. Canada, Trans., ser. 3, vol. 16, p. 160 (*non* Massalongo, 1851, Piante foss. terr. terz. Vicentino osserv., p. 44).

Typification: Palaeochara acadica Bell, 1922, p. 160, pl. 1, figs. 3-9 (type of genus).

Palaeochara Bell is a Pennsylvanian organ-genus of gyrogonites represented solely by the type species. The genus

has been put in an independent family, the Palaeocharaceae, of the order Charales. It is characterized by having six enveloping cells (all the other organ-genera of this order have only five cells) and by its large open apical pore, which is not bordered by a dehiscence furrow.

A rather intricate problem of nomenclature is associated with the name *Palaeochara*. From the Eocene of Monte Bolca, Italy, Massalongo (1850, p. 36) described some fossils as *Chondrites rigidus*. In the following year, the same author (Massalongo, 1851, p. 44) renamed this fossil *Palaeochara rigida*, the name referring to supposed similarities with Recent charophytes with respect to furcation and other characters. After having been quoted occasionally, the fossil designations *Chondrites rigidus* and *Palaeochara rigida* disappeared almost entirely from the phytopaleontological literature. It is rather significant that they are not even quoted as synonyms by Meschinelli and Squinabol (1892) in their comprehensive survey of the Italian Tertiary floras. Although, in this particular case, the reason for the omission is not expressly stated, it is well known that the majority of *Chondrites* and similar fossils are not algae but "Lebensspuren" of various kinds. It is known, moreover, that in several papers Massalongo described many "species" of "*Chondrites*," "*Dictyotites*," and other forms, several of which have proven not to be plants.

From the nomenclatural point of view, however, the name *Palaeochara* Massalongo is legitimate and validly published. This implies that the later homonym *Palaeochara* Bell is illegitimate, and must be replaced by another name because of the homonymy rule (Int. Code Bot. Nom., Art. 74). According to Article 6 of the International Code, the homonymy rule is applicable here, although *Palaeochara* Massalongo cannot with certainty be proved to be a plant.

The best procedure in the present case appears to be (1) to reject the name *Palaeochara* Massalongo as a *nomen inquirendum et confusum*, and (2) to conserve the name *Palaeochara* Bell over earlier homonyms, and to place it in the list of *nomina generica conservanda*.

Genus **Palaeonitella** (Kidston and Lang) Pia

Palaeonitella (Kidston and Lang) Pia in Hirmer, 1927, Handb. Paläobot., vol. 1, p. 91.

Algites, (?)subgenus *Palaeonitella* Kidston and Lang, 1921, Roy. Soc. Edinburgh, Trans., vol. 52, pt. 4, p. 876.

Typification: Palaeonitella Cranii (Kidston and Lang) Pia, 1927, p. 91, text-fig. 75 (type of genus) (*Algites (Palaeonitella) Cranii* Kidston and Lang, 1921, p. 876, text-figs. 1-11, pl. 8, figs. 91-97, pl. 9).

The originally intended taxonomic rank of this genus, generally ascribed to Kidston and Lang, is somewhat doubtful. The authors themselves say (Kidston and Lang, 1921, p. 881): "We have indicated the uncertainty . . . of the remains . . . by placing them for the present in the comprehensive genus *Algites*. On the ground, however, of various features . . . we provisionally suggest the generic name *Palaeonitella*. We thus for the present name the plant *Algites (Palaeonitella) Cranii;* the name *Palaeonitella* may be definitely adopted . . . or abandoned." According to the International Code of Botanical Nomenclature, Article 43, such a name as *Palaeonitella* has no nomenclatural status ("A name (1) which is not accepted by the author who published it, or (2) which is merely proposed in anticipation of the future acceptance of the group concerned . . . is not validly published"). In such cases, the first author who definitely adopts the name also validates it.

From a taxonomic point of view, the charophyte affinity of *Palaeonitella* is rather uncertain (Groves, 1933, p. 49). This genus is represented only by vegetative remains found in association with psilophytes in the well known Devonian locality of Rhynie, Scotland.

Genus **Palaeoxyris** Brongniart

Palaeoxyris Brongniart, 1828, Ann. Sci. Nat., vol. 15, p. 456.
Spirangium Schimper, 1872, p. 514 (a taxonomic synonym).

Typification: Palaeoxyris regularis Brongniart, 1828, p. 456, pl. 20, fig. 1 (type of genus).

Rhaeto-Liassic fossils referred to *Spirangium* (a later taxonomic synonym of *Palaeoxyris*) were interpreted by Nathorst (1879, p. 88) as related to the Charophyta. *Palaeoxyris* is now believed to represent eggs of shark-like fishes (first by Schenk, 1867, p. 204; the latest survey of the relevant literature was published by Brown, 1950, pp. 594*ff.*; see also Mägdefrau, 1953, pp. 283-284).

Genus **Perimneste** Harris

Perimneste Harris, 1939, Brit. Purb. Char., p. 54.

Typification: Perimneste horrida Harris, 1939, p. 54, text-figs. 8O-Q, 9-13; pls. 13-15; pl. 16, figs. 6, 8, 9 (type of genus).

A Purbeckian genus of Clavatoraceae from England and Switzerland. The generic type is represented by both vegetative and reproductive organs. A few detached gyrogonites in the British material have been referred to *Aclistochara* (Mädler, 1952, p. 4), and later to *Porochara* (Mädler, 1955, p. 271). Antheridia of *Perimneste* described by Peck (1941, p. 295) from the Lower Cretaceous of the Rocky Mountains have been considered utricles (probably of *Atopochara*) by Mädler (1952, p. 8). To some extent the comparative gyrogonite morphology of the Clavatoraceae has been discussed by Horn af Rantzien (1954*a*, pp. 27-33, 49-51).

Genus **Porochara** Mädler

Porochara Mädler, 1955, Geol. Jahrb., vol. 70, p. 271.

Typification: Porochara kimmeridgensis (Mädler) Mädler, 1955, p. 271 (type of genus) (*Aclistochara kimmeridgensis* Mädler, 1952, p. 26, pl. B, figs. 13-19).

A Pennsylvanian to Jurassic gyrogonite organ-genus characterized by having the apical spiral cell tips ending around open pores without developing dehiscence furrows or marked apical inflations. Less than ten species have been described.

Genus **Praechara** Horn af Rantzien

Praechara HORN AF RANTZIEN, 1954, Opera Bot., vol. 1, no. 2, p. 57.

Typification: Praechara mädleri HORN AF RANTZIEN, 1954*a*, p. 62, pl. 5, figs. 6-8 (type of genus).

A Triassic organ-genus of gyrogonites lacking dehiscence furrows and apical inflations of the spiral cell tips. These tips either join in a point or leave a very minute rounded opening. A few species have been referred to this genus.

Genus **Protochara** Womersley and Ophel

Protochara WOMERSLEY AND OPHEL, 1947, Roy. Soc. South Australia, Trans., vol. 71, no. 2, p. 316.

Typification: Protochara australis WOMERSLEY AND OPHEL, 1947, p. 316, text-fig. 1 (type of genus).

A Recent genus including one or possibly two very rare species. *Protochara* has not yet been found in the fossil state, but its fructification morphology seems to indicate that some fossil gyrogonites may be affinities.

Genus **Pseudosycidium** Hacquaert

Pseudosycidium KARPINSKY *ex* HACQUAERT, 1932, Brussels, Mus. Roy. Hist. Nat. Belg., Bull., vol. 8, no. 30, p. 10, text-figs. 5, 7.

Typification: None.

This is taxonomically very close to *Sycidium*, and probably cannot be maintained as a distinct organ-genus. Geologically, it is the oldest charophyte recorded; it is reported to have been collected in the "Silurian" of northern Turkestan (Sinkiang), but no details of this very remarkable find are known, and the stratigraphic record requires corroboration.

The nomenclatural status of *Pseudosycidium* is rather doubtful, first, because it was described with reservation and not definitely adopted by the author concerned, and, second, because no species of *Pseudosycidium* have been named or described; it is, accordingly, untypified.

Genus **Raskyella** Grambast and Grambast

Raskyella GRAMBAST AND GRAMBAST, 1954, Rev. Gén. Bot., vol. 61, p. 669.

Typification: Raskyella peckii GRAMBAST AND GRAMBAST, 1954*b*, p. 670, text-fig. 1 (type of genus).

An exclusively fossil organ-genus comprising gyrogonites of which the apical hood, judging from the original diagnosis, consists of parts that are not direct continuations of the spiral cells but are free from them and are delimited by sutures, which end abruptly at the median lines of the spiral cells. *Raskyella* has been made the type of a distinct subfamily, the Raskyelloideae Grambast and Grambast (1955, p. 1001). The type species is Eocene (Bartonian). A tuberculated species from the Eocene of Hungary, which has also been referred to this genus, is probably a rather distant affinity.

Genus **Rhabdochara** Mädler

Rhabdochara MÄDLER, 1955, Geol. Jahrb., vol. 70, p. 299.

Typification: Rhabdochara langeri (VON ETTINGSHAUSEN) MÄDLER, 1955, p. 299, pl. 26, figs. 25-27 (type of genus) (*Chara langeri* VON ETTINGSHAUSEN, 1872, p. 162, pl. 1, figs. 2-3).

A fossil gyrogonite organ-genus characterized by an apical morphology corresponding to that of the Aclistochareae (*sensu* Mädler), and by sculpture consisting of transverse rods in the cellular furrows. A few species have been recorded from the Paleocene, the Upper Oligocene, and the Lower Miocene.

Genus **Sphaerochara** Mädler

Sphaerochara MÄDLER, 1952, Geol. Jahrb., vol. 67, p. 6.

Typification: Sphaerochara hirmeri (RÁSKY) MÄDLER, 1952, p. 6 (type of genus) (*Chara hirmeri* RÁSKY, 1945, p. 36, pl. 1, figs. 10-12).

A fossil organ-genus comprising gyrogonites without dehiscence furrows and with non-inflated apical cell tips meeting at a point or along a short broken line. The gyrogonites of this genus are more or less spherical. Seven species have been described, from the Middle Triassic, the Cretaceous, and the Oligocene to Pliocene.

Genus **Spirangium** Schimper

Spirangium SCHIMPER, 1872, Pal. végét., vol. 2, p. 514.

Typification: None.

Reference: Palaeoxyris Brongniart (a taxonomic synonym).

Genus **Stellatochara** Horn af Rantzien

Stellatochara HORN AF RANTZIEN, 1954, Opera Bot., vol. 1, no. 2, p. 26.

Typification: Stellatochara sellingii HORN AF RANTZIEN, 1954*a*, p. 33, pls. 1-2 (type of genus).

A Middle Triassic organ-genus of clavatoraceous gyrogonites with apical poles prolonged into beaks, in the centres of which there are large pores. These gyrogonites have no dehiscence furrows, nor are their apical spiral cell tips inflated. Three species have been described.

Genus **Sycidium** Sandberger

Sycidium SANDBERGER, 1849, Neues Jahrb. Min., Geogn., Geol. und Petref. Kunde, vol. 20, p. 671.
?Pseudosycidium KARPINSKY *ex* HACQUAERT, 1932, p. 10.

Typification: Sycidium reticulatum SANDBERGER, 1849, p. 672, pl. 8, fig. B (type of genus).

A Devonian to basal Mississippian and also possibly Silurian (see *Pseudosycidium*) gyrogonite organ-genus with straight, regularly pitted spiral cells of varying numbers and with large apical pores. The charophyte affinities of *Sycidium* gyrogonites were for a long time doubted, but have been convincingly demonstrated by Karpinsky (1906) and by Peck (1934*b*). Type of the order Sycidiales. Seven species have been described.

Genus **Tectochara** Grambast and Grambast

Tectochara GRAMBAST AND GRAMBAST, 1954, Rev. Gén. Bot., vol. 61, p. 668.

Typification: Tectochara merianii GRAMBAST AND GRAMBAST, 1954*b*, p. 668 (type of genus) (*Chara Meriani* BRAUN *ex* HEER, 1855, Fl. Tert. Helv., vol. 1, p. 24, pl. 4, fig. 3; *non* BRAUN *ex* UNGER, 1850, Gen. et spec. pl. foss., p. 34, *neque* BRAUN *ex* UNGER, 1852, Icon. pl. foss., p. 10, pl. 25, figs. 10-12).

A fossil organ-genus comprising gyrogonites with marked dehiscence furrows formed by a considerable spiral cell lumen decrease in the apical periphery and with strongly swollen apical cell tips. The original definition of this genus also included gyrogonites with tuberculated surfaces (see *Nodosochara* Mädler). About fifteen species have been recorded from the Paleocene onward, including one from the Quaternary (Mädler, 1955, p. 284).

Mädler (1955, pp. 277-278) has pointed out that the nomenclature of the type species is rather complicated. Unger (1850, p. 34) described and later illustrated (Unger, 1852, pl. 25, figs. 10-12) a gyrogonite species from Sagor in Krain, Yugoslavia, as *Chara Meriani* Alex. Braun MS. Heer (1855, p. 24, pl. 4, fig. 3a-o) also described and illustrated gyrogonites from Lausanne and Basel, Switzerland, as *Chara Meriani* Alex. Braun, but these were distinctly different from Unger's species. Heer listed the latter as a synonym, although he remarked that Unger's figure 10 (1852) did not belong to *Chara Meriani*. Heer quoted Braun in support of the correctness of his identification: "Ich habe welche davon [gyrogonites from Lausanne] an Herrn Professor A. Braun gesandt, der sie ebenfalls für seine *Ch. Meriani* erklärt hat, so dass über die Richtigkeit der Bestimmung nicht der geringste Zweifel walten kann." On the basis of new collections from the Sagor locality, von Ettingshausen (1872, p. 162) described some gyrogonites as *Chara Ungeri*, quoting Unger's figure 10 (1852) as a synonym.

Chara Meriani, in the sense of Heer, has proved to be widely distributed in late Tertiary deposits of Europe and elsewhere (Mädler, 1955, pp. 277-285). It has, moreover, been chosen as the generic type of *Tectochara* (Grambast and Grambast, 1954*b*), and its taxonomy has been very thoroughly dealt with by Mädler (1955). Nomenclaturally, Mädler has chosen Heer's illustrations (1855, pl. 4, fig. 3a-o) as the lectotype of *Tectochara meriani*. All of the three types of gyrogonites illustrated by Unger (1852, pl. 25, figs. 10-12), not merely figure 10, are considered distinct from *Tectochara meriani* by Mädler.

Nomenclaturally speaking, this situation may be summed up as follows: *Chara Meriani* is a legitimate name that was validly published and illustrated by Unger (1850, 1852). *Chara Ungeri* von Ettingshausen (1872) is a later synonym of *Chara Meriani* Unger and, as such, illegitimate. It might be added that the taxonomic position is difficult to judge from Unger's illustrations, but *Chara Meriani* Unger does not seem referable to *Tectochara*.

Heer's (1855) *Chara Meriani* (the *Chara meriani* of most subsequent authors) is a later homonym of *Chara Meriani* Unger and, accordingly, illegitimate. Renaming it would cause a number of inconvenient new combinations of infraspecific categories, but fortunately there seems to be no immediate reason to do so. Article 81 of the International Code of Botanical Nomenclature deals with similar cases, stating: "When a new epithet is required, an author may, if he wishes, adopt an epithet previously given to the taxon in an illegitimate combination, if there is no obstacle to its employment in the new position or sense; the epithet in the resultant combination is treated as new." As the name *Chara Meriani* Heer is illegitimate, it is, accordingly, possible to consider *Tectochara merianii* Grambast and Grambast (1954*b*, p. 668) as an entirely new name. In this case, the generic type should be cited as "*Tectochara merianii* Grambast and Grambast," without the parenthetic "Braun *ex* Heer." However, should *Chara Meriani* Unger later prove to belong to *Tectochara*, which seems rather improbable, the generic type would have to be renamed.

Genus **Tolypella** (Braun) von Leonhardi

Tolypella (BRAUN) VON LEONHARDI, 1863, Lotos, vol. 13, p. 72.
Nitella, subgenus *Tolypella* BRAUN, 1849, p. 199 (*pro parte*).

Typification: Tolypella glomerata (DESVAUX) VON LEONHARDI, 1863*b*, p. 129 (lectotype of genus, HORN AF RANTZIEN AND OLSEN, 1949, p. 99) (*Chara glomerata* DESVAUX in LOISELEUR, 1810, p. 135, *pro parte*).

Tolypella is a well-defined Recent genus with thirteen recognized species. Eight species of fossil gyrogonites (Kimmeridgian and Eocene to Miocene) have been thought sufficiently similar to the female gametangia and fructifications of living *Tolypella* to be included here.

Genus **Tolypellopsis** (von Leonhardi) Migula

Tolypellopsis (VON LEONHARDI) MIGULA, 1897, Char. Deutschl., Oesterr., Schw., p. 253.
Chara, subgenus *Tolypellopsis* VON LEONHARDI, 1863*a*, p. 73.

Typification: Tolypellopsis stelligera (Reichenbach) Migula, 1897, p. 255 (type of genus) (*Chara stelligera* Reichenbach, 1829, p. 1595).

Reference: Nitellopsis Hy (a nomenclatural synonym).

Genus **Trochiliscus** Karpinsky

Trochiliscus (Pander *ex*) Karpinsky, 1906, St. Pétersbourg, Com. Géol., Mém., new ser., vol. 27, p. 123.
Calcisphaera Williamson, 1880, p. 520 (*pro parte min.*) (taxonomic synonym).
Moellerina Ulrich, 1886, p. 34 (taxonomic synonym).

Typification: Trochiliscus ingricus Karpinsky, 1906, p. 112, pl. 2, figs. 22-28 (lectotype of genus, Peck, 1934*b*, p. 105).

Trochiliscus is a Downtonian to basal Mississippian organ-genus, comprising gyrogonites with dextrally spiralled enveloping cells of varying numbers, ending around apical pores. This group has recently (Croft, 1952, p. 209) been divided into two subgenera, *Eutrochiliscus* Croft and *Karpinskya* Croft, but each of these might equally well have been given generic rank. The genus *Trochiliscus*, which comprises about twenty species, is the type of the order Trochiliscales. Karpinsky ascribed this genus to Pander (1856, p. 17), but Pander gave no formal description, and for that reason cannot be considered its author (see Peck, 1934*b*, p. 105).

BIBLIOGRAPHY

Agardh, C. A.
1824 – *Systema Algarum.* Lund: Berling, pp. i-xxxviii, 1-312.

Bell, W. A.
1922 – *A new genus of Characeae and new Merostomata from the Coal Measures of Nova Scotia.* Roy. Soc. Canada, Trans., ser. 3, vol. 16, pp. 159-167, pl. 1.

Braun, A.
1849 – *Charae Australes et Antarcticae, or characters and observations on the Characeae of Australia and the southern circumpolar regions.* Hooker's Jour. Bot., vol. 1, pp. 193-203.

Braun, A., and Nordstedt, O.
1883 – *Fragmente einer Monographie der Characeen.* K. Akad. Wiss. Berlin, Abh., Jahrg. 1882, pp. 1-211, pls. 1-7.

Brongniart, Ad.
1822 – *Sur la classification et la distribution des végétaux fossiles en général, et sur ceux des terrains de sédiment supérieur en particulier.* Paris, Mus. National Hist. Nat., Mém., vol. 8, pp. 203-240, 297-348, pls. 12-17.

1828 – *Essai d'une flore du grès bigarré.* Ann. Sci. Nat., vol. 15, pp. 435-460, pls. 15-20.

Bronnimann, P.
1955 – *Microfossils incertae sedis from the Upper Jurassic and Lower Cretaceous of Cuba.* Micropaleontology, vol. 1, no. 1, pp. 28-51, pls. 1-2, text-figs. 1-10, chart 1.

Brown, R. W.
1950 – *Cretaceous fish egg capsule from Kansas.* Jour. Pal., vol. 24, no. 5, pp. 594-600, text-figs. 1-9.

Croft, W. N.
1952 – *A new Trochiliscus (Charophyta) from the Downtonian of Podolia.* Brit. Mus. (Nat. Hist.), Bull., Geol., vol. 1, no. 7, pp. 189-220, pls. 18-19, text-figs. 1-7.

Cuvillier, J.
1951 – *Corrélations stratigraphiques par microfaciès en Aquitaine occidentale.* Leiden: Brill, pp. 1-21, pls. 1-90, chart 1.

Desvaux, A. N.
1810 – see Loiseleur Deslongchamps.

Edwards, W. N.
1932 – *Lower Eocene plants from Istria.* Ann. Mag. Nat. Hist., ser. 10, vol. 10, pp. 213-216, pl. 10.

Ettingshausen, C. von
1872 – *Die fossile Flora von Sagor in Krain; 1.* K. Akad. Wiss. Wien, Math.-Naturw. Cl., Denkschr., vol. 32, pp. 159-202, pls. 1-10.

Filarszky, F.
1937 – *Idegenföldi charafélék határozása (Determinatio Characearum exoticarum).* Magyar Tudom. Akad., Math.-Termés. Értes., vol. 55, pp. 476-497, text-figs. 1-45 (German summary, pp. 496-497: *Bestimmungen einiger exotischen Characeen*).

Grambast, L., and Grambast, N.
1953 – *Revision de quelques charophytes tertiaires du Bassin de Paris.* Soc. Géol. France, C. R. Somm., no. 14, pp. 289-291.

1954*a* *Sur deux espèces de charophytes du Bartonien du Bassin de Paris.* Ibid., no. 4, pp. 95-97, text-fig. 1.

1954*b* *Sur la position systématique de quelques charophytes tertiaires.* Rev. Gén. Bot., vol. 61, pp. 665-671, text-fig. 1.

1955 – *Les Raskyelloideae, sous-famille fossile des Characeae.* Acad. Sci., C. R., vol. 240, pp. 999-1001, text-figs. 1-4.

Groves, J.
1916 – *On the name Lamprothamnus Braun.* Jour. Bot., British and Foreign, vol. 54, pp. 336-337.

1919 – *Notes on Lychnothamnus.* Ibid., vol. 57, pp. 125-129.

1924 – *Clavator Reid & Groves.* Ibid., vol. 62, pp. 116-117.

1933 – *Charophyta.* In: Jongmans, W. (ed.), Fossilium Catalogus, II (Plantae), fasc. 19, pp. 1-74.

Hacquaert, A. L.
1932 – *Notes sur les genres Sycidium et Trochiliscus.* Brussels, Mus. Roy. Hist. Nat. Belg., Bull., vol. 8, no. 30, pp. 1-22, text-figs. 1-10.

Harris, T. M.
1939 – *British Purbeck Charophyta.* London: Brit. Mus. (Nat. Hist.), pp. i-ix, 1-83, pls. 1-17, text-figs. 1-16.

Heer, O.
1855 – *Flora Tertiaria Helvetiae.* Winterthur: Wurster, vol. 1, pp. i-vi, 1-117, pls. 1-50.

Horn af Rantzien, H.
1954*a* *Middle Triassic Charophyta of South Sweden.* Opera Bot., vol. 1, no. 2, pp. 1-83, pls. 1-7, text-figs. 1-3, tables 1-3.

1954*b* *Revisions of some Pliocene charophyte gyrogonites.* Bot. Not., fasc. 1, pp. 1-33, text-figs. 1-8.

Horn af Rantzien, H., and Olsen, S.
1949 – *A suggested starting-point for the nomenclature of Charophyta.* Svensk Bot. Tidsskr., vol. 43, no. 1, pp. 98-106.

Hy, F.
1889 – *Sur les modes de ramification et de cortication dans la famille des Characées, et les charactères qu'ils peuvent fournir à la classification.* Soc. Bot. France, Bull., vol. 36, pp. 393-398.

1890 – *Sur les caractères généraux de la famille des Characées et leur importance taxonomique.* Rev. Bot., Toulouse, vol. 8, pp. 25-47.

JONGMANS, W.
1936 – *Lycopodiales; V (incl. Hydropteridae, Psilophytales Sphenophyllales).* In: JONGMANS, W. (ed.), Fossilium Catalogus, II (Plantae), fasc. 21, pp. 999-1188.

KAMPTNER, E.
1931 *Nannoconus steinmanni nov. gen., nov. spec., ein merkwürdiges gesteinsbildendes Mikrofossil aus dem jüngeren Mesozoikum der Alpen.* Pal. Zeitschr., vol. 13, no. 4, pp. 288-298, text-figs. 1-3.

KARPINSKY, A.
1906 – *Die Trochilisken.* St. Pétersbourg, Com. Géol., Mém., new ser., vol. 27, pp. i-viii, 1-166, pls. 1-3, text-figs. 1-59.

KIDSTON, R., AND LANG, W. H.
1921 – *On Old Red Sandstone plants, showing structure, from the Rhynie Chert Bed, Aberdeenshire; Part V—The Thallophyta occurring in the peat-bed; the succession of the plants throughout a vertical section of the bed, and the conditions of accumulation and preservation of the deposit.* Roy. Soc. Edinburgh, Trans., vol. 52, pt. 4, pp. 855-902, pls. 1-10, text-figs. 1-11.

KNOWLTON, F. H.
1889 – *Description of a problematic organism from the Devonian at the Falls of the Ohio.* Amer. Jour. Sci., vol. 37, pp. 202-209, text-figs. 1-3.

KRÄUSEL, R., AND WEYLAND, H.
1933 – *Die Flora des böhmischen Mitteldevons (Stufe Hh, Barrande = h Kettner-Kodym).* Palaeontographica, vol. 78, pt. B, pp. 1-46, pls. 1-7, text-figs. 1-39.

KREJČI, J.
1880 – *Notiz über die Reste von Landpflanzen in der böhmischen Silurformation.* K. Böhm. Ges. Wiss., Sitzb., Jahrg. 1879, no. 22, pp. 201-204.

KÜTZING, F. T.
1843 – *Phycologia generalis oder Anatomie, Physiologie und Systemkunde der Tange.* Leipzig: Brockhaus, pp. i-xxxii, 1-458, pls. 1-80.

LAMARCK, J. B. A. P. M. DE
1804 – *Suite des mémoires sur les fossiles des environs de Paris.* Paris, Mus. National Hist. Nat., Ann., vol. 5, pp. 349-357.

1807 – *Explication des planches relatives aux coquilles fossiles des environs de Paris.* Paris, Mus. National Hist. Nat., Ann., vol. 9, pp. 236-240, 399-401, pls. 15-20 (17-20, 31-32).

1822 – *Histoire naturelle des animaux sans vertèbres.* Paris: the author, vol. 7, pp. 1-711.

LANGE, F. W.
1954 – *News Report – Brazil.* Micropaleontologist, vol. 8, no. 2, pp. 11-13.

LEONHARDI, H. VON
1863*a* *Ueber die böhmischen Characeen.* Lotos, vol. 13, pp. 55-62, 69-80.

1863*b* *Weitere Characeen-Fundorte.* Lotos, vol. 13, pp. 129-132.

LINNAEUS, C.
1753 – *Species plantarum.* Stockholm: Salvius, vol. 1, ed. 1, pp. 1-560.

1754 – *Genera plantarum.* Stockholm: Salvius, ed. 5, pp. i-xxxii, 1-500.

LOISELEUR DESLONGCHAMPS, J. L. A.
1810 – *Notice sur les plantes à ajouter à la flore de France.* Paris: Sajou, pp. 1-169, pls. 1-6.

LU, Y.-H.
1945 – *The Charophyta from the Kucha formation near Kucha, Sinkiang.* Geol. Soc. China, Bull., vol. 24 (1944), no. 1-2, pp. 33-36, pl. 1.

MÄDLER, K.
1952 – *Charophyten aus dem Nordwestdeutschen Kimmeridge.* Geol. Jahrb., vol. 67, pp. 1-46, pls. A-B, text-figs. 1-8.

1955 – *Zur Taxionomie der tertiären Charophyten.* Ibid., vol. 70, pp. 265-328, pls. 23-26, tables A-C.

MÄGDEFRAU, K.
1953 – *Paläobiologie der Pflanzen.* Jena: Fischer, ed. 2, pp. i-x, 1-438, text-figs. 1-321.

MASSALONGO, A.
1850 – *Schizzo geognostico sulla valle del progno o torrente d'Illasi con un saggio sopra la flora primordiale del M. Bolca.* Verona: Antonelli, 77 pp. (not seen).

1851 – *Sopra le piante fossili dei terreni terziari del Vicentino osservazioni.* Padua: Bianchi, 263 pp. (not seen).

MESCHINELLI, A., AND SQUINABOL, X.
1892 – *Flora Tertiaria Italica.* Padua: the authors, pp. i-lxii, 1-575.

MEYEN, F. J. F.
1827 – *Beobachtungen und Bemerkungen über die Gattung Chara.* Linnaea, vol. 2, pp. 55-81, pls. 2-3.

MIGULA, W.
1897 – *Die Characeen Deutschlands, Oesterreichs und der Schweiz.* In: RABENHORST, L., *Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz.* Leipzig: Kummer, ed. 2, vol. 5, pp. i-xvi, 1-765, text-figs. 1-149.

MILLER, S. A.
1889 – *North American geology and palaeontology.* Cincinnati, Ohio: the author, pp. 1-664, text-figs. 1-1194.

NATHORST, A. G.
1879 – *Om Spirangium och dess förekomst i Skånes kolförande bildningar. (On Spirangium and its occurrence in the Rhaeto-Liassic of Scania, South Sweden).* K. Vet.-Akad., Öfvers. Förhandl., vol. 36, no. 3, pp. 81-93, pls. 6-7.

PANDER, H. C.
1856 – *Monographie der fossilen Fische des Silurischen Systems des Russisch-Baltischen Gouvernements.* St. Petersburg: K. Akad. Wiss., pp. i-x, 1-91, pls. 1-7, text-figs 1-10.

PAPP, A.
1951 – *Charophytenreste aus dem Jungtertiär Österreichs.* Österr. Akad. Wiss., Math.-Naturw. Kl., Sitzb., Abt. 1, vol. 160, nos. 3-4, pp. 279-293, pls. 1-4, text-fig. 1.

PECK, R. E.
1934*a* *Late Paleozoic and early Mesozoic Charophyta.* Amer. Jour. Sci., ser. 5, vol. 27, no. 157, pp. 49-55, 1 pl.

1934*b* *The North American trochiliscids, Paleozoic Charophyta.* Jour. Pal., vol. 8, no. 2, pp. 83-119, pls. 9-13, text-figs. 1-2.

1937 – *Morrison Charophyta from Wyoming.* Ibid., vol. 11, no. 2, pp. 83-90, pl. 14.

1938 – *A new family of Charophyta from the Lower Cretaceous of Texas.* Ibid., vol. 12, no. 2, pp. 173-176, pl. 28, text-fig. 1.

1941 – *Lower Cretaceous Rocky Mountain nonmarine microfossils.* Ibid., vol. 15, no. 3, pp. 285-304, pls. 42-44.

PECK, R. E., AND REKER, C. C.
1947 – *Cretaceous and Lower Cenozoic Charophyta from Peru.* Amer. Mus. Novitates, no. 1369, pp. 1-6, text-figs. 1-27.

1948 – *Eocene Charophyta from North America.* Jour. Pal., vol. 22, no. 1, pp. 85-90, pl. 21.

PIA, J.
1927 – *Thallophyta.* In: HIRMER, M., *Handbuch der Paläobotanik.* Munich and Berlin: Oldenbourg, vol. 1, pp. 31-136, text-figs. 14-129.

RAFINESQUE, C. S.
1815 – *Analyse de la nature; ou, Tableau de l'univers et des corps organisés.* Palermo: 224 pp. (not seen).

1819 – *Prodrome des nouveaux genres des plantes observées en 1817 et 1818 dans l'intérieur des États Unis d'Amérique.* Jour. Phys., Chimie, Hist. Nat. et Arts, vol. 89, p. 107 (not seen).

1825 – *Neogenyton, or indication of sixty-six new genera of plants of North America.* Lexington, Ky. [?] (not seen).

1836 – *Flora Telluriana.* Lexington, Ky.: vol. 1 (not seen).

RÁSKY, K.
1945 – *Fossile Charophyten-Früchte aus Ungarn.* Budapest, Ungar. Naturw. Mus., Naturw. Monogr., vol. 2, pp. 1-74, pls. 1-3, 1 map.

REICHENBACH, H. G. L.
1829 – *Dr. Joh. Christ. Mössler's Handbuch der Gewächskunde.* Altona, Germany: Hammerich, vol. 3, ed. 2, pp. i-xxxiv, 1583-1963.

REID, C., AND GROVES, J.
1916 – *Preliminary report on the Purbeck Characeae.* Roy. Soc., London, Proc., ser. B, vol. 89, pp. 252-256, pl. 8.

1921 – *The Charophyta of the Lower Headon Beds of Hordle (Hordwell) Cliffs (South Hampshire).* Geol. Soc. London, Quart. Jour., vol. 77, no. 3, pp. 175-192, pls. 4-6.

RUPRECHT, F. J.
1845 – *Distributio cryptogamarum vascularium in Imperio Rossico.* Petropolis: Acad. Sci., pp. 1-56.

SAHNI, B., AND RAO, S. R. N.
1943 – *On Chara sausari sp. nov., a Chara (sensu stricto) from the Intertrappean Cherts at Sausar in the Deccan.* Nat. Acad. Sci. India, Proc., vol. 13, no. 3, pp. 215-223, text-figs. 1-8.

SALTER, J. W.
1856 – *Note on the gyrogonites (Chara).* In: FORBES, E., *On the Tertiary fluvio-marine formation of the Isle of Wight.* Great Britain, Geol. Survey, Mem., pp. 159-161, pl. 7 (not seen).

SANDBERGER, G.
1849 – *Eine neue Polypen-Gattung Sycidium aus der Eifel.* Neues Jahrb. Min., Geogn., Geol. und Petref.-Kunde, vol. 20, pp. 671-672, pl. 8 (B 1).

SCHENK, A.
1867 – *Die fossile Flora der Grenzschichten des Keupers und Lias Frankens.* Wiesbaden: Kreidel, pp. i-xxiv, 1-232, pls. 1-45.

SCHIMPER, W. P.
1872 – *Traité de paléontologie végétale ou la flore du monde primitif dans ses rapports avec les formations géologiques et la flore du monde actuel.* Paris: Baillière, vol. 2, pp. 1-968.

STACHE, G.
1872 – *Ueber neue Characeenreste aus der oberen Abtheilung der liburnischen Stufe bei Pisino in Istrien.* Austria, Geol. Reichsanst., Verh., no. 15, pp. 316-317.

1880 – *Die Liburnische Stufe.* Ibid., no. 12, pp. 195-209.

1889 – *Die Liburnische Stufe und deren Grenz-Horizonte: Eine Studie über die Schichtenfolgen der cretacisch-eocänen oder protocänen Landbildungsperiode im Bereiche der Küstenländer von Österreich-Ungarn; Erste Abtheilung – Geologische Übersicht und Beschreibung der Faunen- und Floren-Reste.* Austria, Geol. Reichsanst., Abh., vol. 13, no. 1, pp. 1-170, pls. 1-6, 1 map.

STERNBERG, K.
1825 – *Versuch einer geognostisch-botanischen Darstellung der Flora der Vorwelt.* Leipzig and Prague: Fleischer, vol. 1, fasc. 4, pp. 1-48, i-xlii, pls. 40-59, A-E.

STUR, D.
1881 – *Die Silur-Flora der Etage H-h_1 in Böhmen.* K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber., vol. 84, pt. 1, pp. 330-391, pls. 1-5.

TUZSON, J.
1914 – *Beiträge zur fossilen Flora Ungarns (Additamenta ad floram fossilem Hungariae III).* Hungary, K. Ungar. Geol. Reichsanst., Mitt. Jahrb., vol. 21, no. 8, pp. 233-261, pls. 13-21.

ULRICH, E. O.
1886 – *Descriptions of new Silurian and Devonian fossils.* Contr. Amer. Pal., Cincinnati, Ohio, vol. 1, pp. 3-35, pls. 1-3, 2 text-figs.

UNGER, F.
1850 – *Genera et species plantarum fossilium.* Vienna: Braumüller, pp. i-xl, 1-627.

1852 – *Iconographia plantarum fossilium.* K. Akad. Wiss. Wien, Math.-Naturw. Cl., Denkschr., vol. 4, pp. 73-118, pls. 1-22.

WALLMAN, J.
1853 – *Försök till en systematisk uppställning av växtfamiljen Characeae (Attempts towards a systematic classification of the family Characeae).* Stockholm: Norstedt, pp.1-103.

WALLROTH, F. W.
1833 – *Flora cryptogamica Germaniae.* Nuremberg: Schrag, vol. 2, pp. i-lvi, 1-923.

WILLIAMSON, W. C.
1880 – *On the organization of the fossil plants of the coal-measures; Part 10, including an examination of the supposed radiolarians of the Carboniferous rocks.* Roy. Soc. London, Philos. Trans., vol. 171, no. 14, pp. 493-539, pls. 14-21.

WOMERSLEY, H. B. S., AND OPHEL, I. L.
1947 – *Protochara, a new genus of Characeae from Western Australia.* Roy. Soc. South Australia, Trans., vol. 71, no. 2, pp. 311-317, text-figs. 1-2.

WOOD, R. D.
1948 – *On Rafinesque's names for the Characeae.* Torrey Bot. Club, Bull., vol. 75, no. 3, pp. 282-285.

1952 – *The Characeae, 1951.* Bot. Rev., vol. 18, no. 5, pp. 317-353.

ABSTRACT: *Climatic curves derived from variations in planktonic foraminifera in three deep-sea cores are compared with isotopic temperature curves drawn by Emiliani on the basis of the same cores. There is close correlation in the upper part of the section, but increasing deviation downward.*

Micropaleontological and isotopic determinations of Pleistocene climates

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INTRODUCTION

The pioneer work of Schott (1935) on sediment cores collected in the equatorial Atlantic by the Meteor Expedition opened up a new approach to the problem of Pleistocene climates. Schott concluded that vertical variations in the abundance of *Globorotalia menardii* in the cores probably corresponded with alternations of cold and warm climate during the Pleistocene.

In the following years, many cores were taken in the Atlantic and Caribbean by means of the Piggot coring tube and later with the Stetson free-fall corer. The foraminifera in some of these cores were studied by Cushman and Henbest (1940) and by Cushman (1941), and in others by Phleger (1939, 1942). However, because of friction between the sediment and the wall of the coring tube, the longest cores that could be taken with these corers were about three meters.

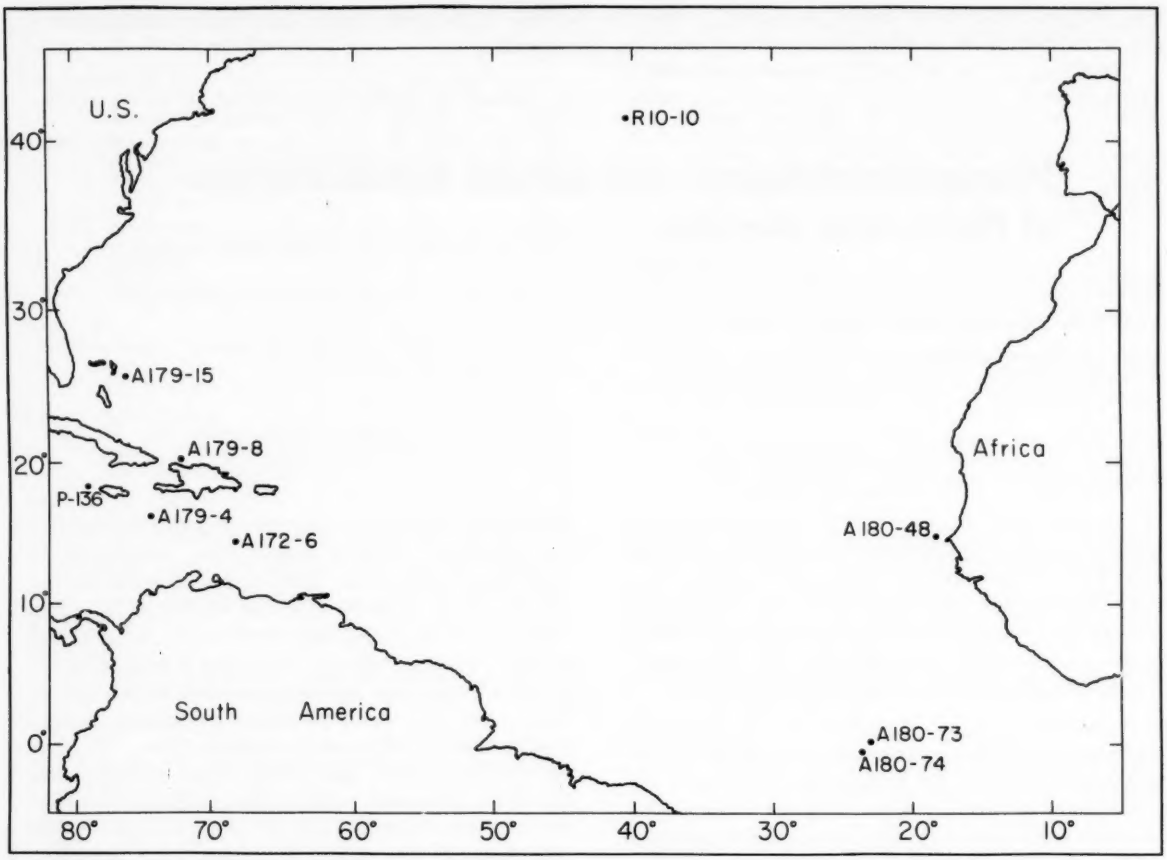
A great advance in coring technique was brought about by the invention of the piston coring tube by Kullenberg (1944, 1947, 1955), which is capable of taking cores twenty meters long. It has the additional very important advantage that it recovers undistorted cores which truly represent the sedimentary section as it is *in situ* (Kullenberg, 1947; Ericson and Wollin, 1956). In this respect it is unlike the older corers, in which there is progressive shortening of the section as friction between the sediment and the coring-tube wall builds up. About 200 piston cores were taken by the Swedish Deep-Sea Expedition under the direction of Hans Pettersson. The foraminifera in cores selected from this collection have been studied by Schott (1952) and by Ovey (1950), and a suite of thirty-nine taken in the Atlantic have been reported on by Phleger, Parker and Peirson (1953).

During the past nine years, W. Maurice Ewing and his associates, using a piston corer developed by Kullenberg (1944, 1947, 1955) and modified by Ewing (Ewing *et al.*, 1954; Ericson and Wollin, 1956), have taken over a thousand long cores in the Atlantic and adjacent seas. Conclusions regarding processes of deposition in the deep basins reached through study of these cores have been published by Ericson, Ewing and Heezen (1952), and by Ericson, Ewing, Heezen and Wollin (1955). They have found evidence that disturbing processes, such as slumping and turbidity currents, have been far more prevalent than previously supposed. In fact, cores containing long unbroken records of Pleistocene events are exceptional, rather than the rule. The three cores discussed in detail in this paper have been chosen because, we believe, they contain undisturbed sections.

The Lamont collection of cores has been growing at the rate of more than a hundred cores a year. In order to keep up with this quantity of material, it was necessary to make use of a rapid method of foraminiferal analysis. The results of its application to over 200 selected deep-sea cores will be published in a paper now in preparation. It has been found that this method is sufficiently sensistive to detect certain faunal zones in the cores which are characterized by dominance of either low-latitude or high-latitude species.

The oxygen-isotope method of determining paleotemperatures developed by Urey (1947) was applied to the core samples to check the validity of the record of climatic changes indicated by this method. The results derived from the isotopic analyses of samples from three of the cores have been reported by Emiliani

micropaleontology, vol. 2, no. 3, pp. 257-270, text-figs. 1-7, tables 1-5, july, 1956



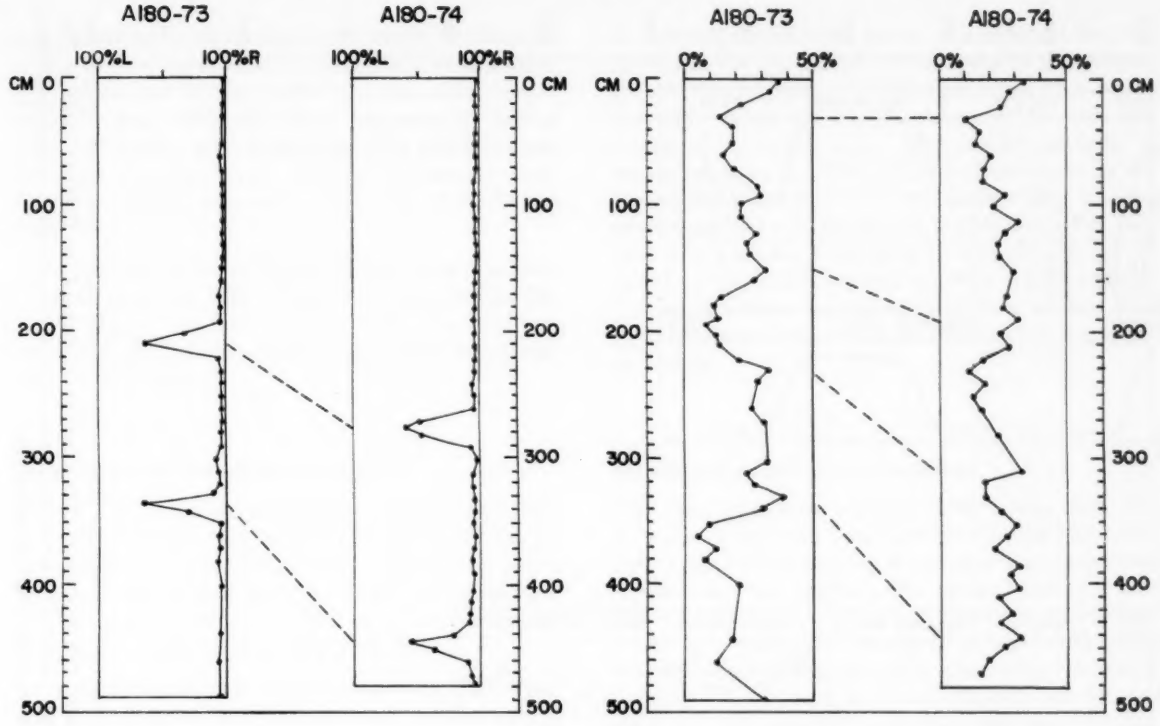
TEXT-FIGURE 1

OUTLINE MAP OF THE ATLANTIC OCEAN SHOWING LOCATION OF CORING STATIONS

TABLE 1

LOCATIONS, DEPTHS AND LENGTHS OF THE CORES

Core no.	Latitude	Longitude	Depth (meters)	Length (cm.)
A172–6	14°59′ N.	68°51′ W.	4160	935
A179–4	16°36′ N.	74°48′ W.	2965	690
A179–8	20°29′ N.	72°49′ W.	4060	485
A179–15	24°48′ N.	75°56′ W.	3110	560
A180–48	15°19′ N.	18°06′ W.	1450	530
A180–73	00°10′ N.	23°00′ W.	3750	490
A180–74	00°03′ S.	24°10′ W.	3330	480
R10–10	41°24′ N.	40°06′ W.	4755	415
P–136	18°38′ N.	79°12′ W.	4650	190



TEXT-FIGURE 2

Correlation based on the coiling direction of *Globorotalia truncatulinoides* and the weight of the $> 74\mu$ fractions of two cores from the equatorial Atlantic. The curves on the left are based on the percentage ratios between right- and left-coiling shells of *Globorotalia truncatulinoides;* L indicates left and R right. The curves on the right are based on the percentages of the weights of the $> 74\mu$ fractions.

(1955). Since various discrepancies appeared between the climatic curves obtained by the rapid method of foraminiferal analysis and the curves of paleotemperatures, it was evident that a more precise method of faunal analysis was needed.

THE CORES

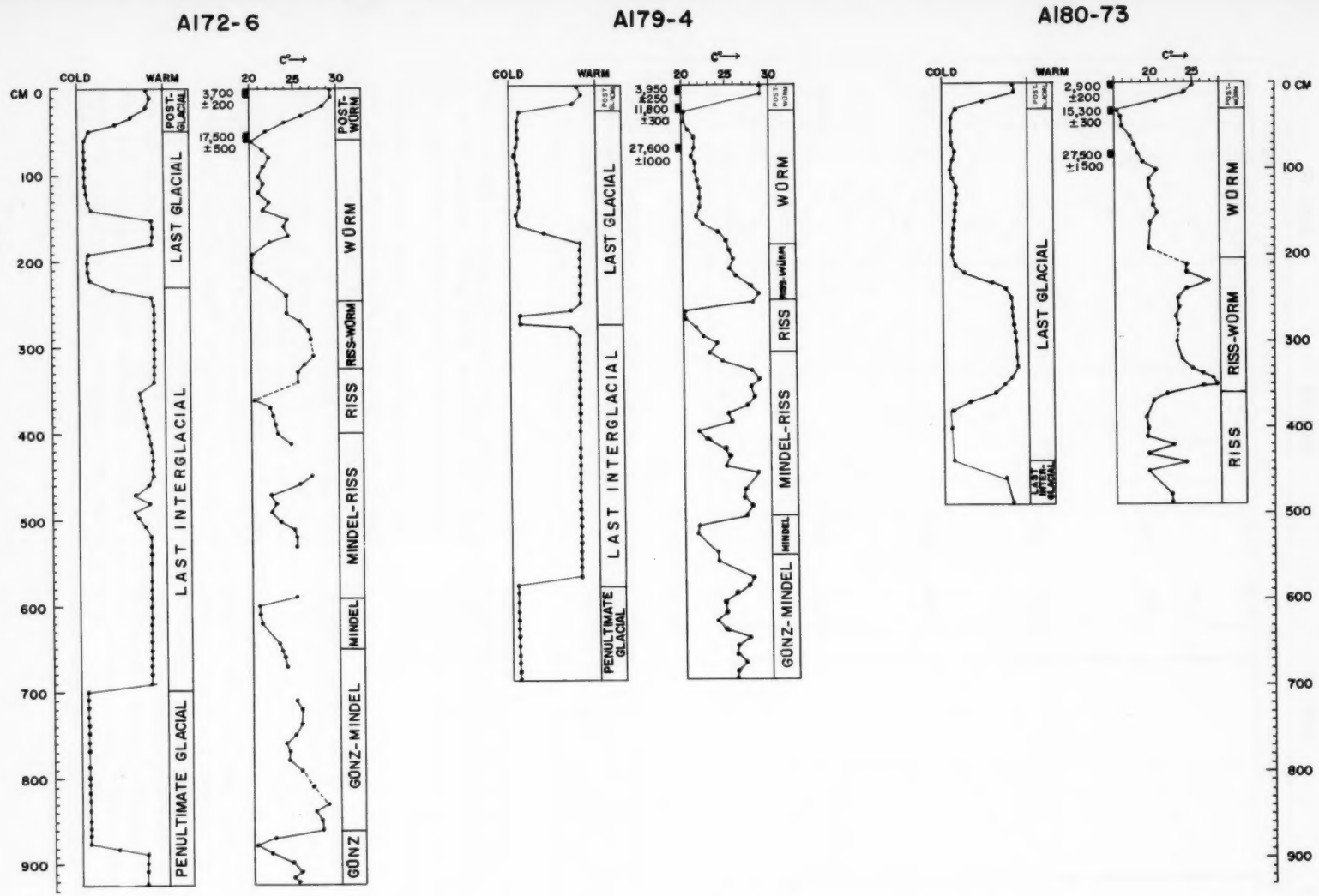
Table 1 gives the positions of the coring stations, depths of water, and lengths of the cores (see also text-figure 1).

Core A172-6 was taken on the crest of an eastern extension of the Beata Ridge near the center of the eastern Caribbean. The sediment is a brown foraminiferal lutite. (The term "lutite" has been applied to indicate a sediment in which all particles are smaller than the silt fraction, regardless of whether it consists of clay minerals, calcite, or some other mineral.)

Core A179-4 is from a gentle slope southeast of the Albatross Bank in the Caribbean. The sediment is a foraminiferal lutite in various shades of brown. There is no bedding except between centimer 250 and centimeter 400, and here it is poorly defined. There is abundant evidence of burrowing throughout the core.

Core A180-73 is from the gently sloping northeast flank of the Mid-Atlantic Ridge. The top of the core is a grayish tan foraminiferal lutite which gradually becomes darker to centimeter 35, at which point there is a fairly abrupt color change to light gray, which continues with minor changes in shade to centimeter 225. Below centimeter 225 there are alternating layers, 20 to 40 centimeters thick, of brown and gray lutite. The texture is uniform. There is some evidence of burrowing throughout the core.

The evidence for an undisturbed section in this core is based on correlation between this core and three others which make a profile nearly 500 kilometers long. The close correlation indicates that the orderly process of particle-by-particle accumulation has not



TEXT-FIGURE 3

Comparison of climatic curves derived from variations in foraminifera with oxygen-isotope paleotemperature curves. In each pair of curves, the curve to the right shows the isotopic temperatures obtained from *Globigerinoides sacculifer*, with the Pleistocene chronology as interpreted by Emiliani (1955). The curves to the left are based on the relative numbers of warm-water and cold-water planktonic foraminifera. Between each pair of curves, radiocarbon dates in years B.P., according to Suess (1956), are given, with the blacked-out zone indicating the range of the sample.

been interfered with by turbidity currents or slumping in any of these cores. This evidence has been discussed by Ericson and Wollin (1956). In this series, correlation by gross lithology is fully supported by coiling curves of *Globorotalia truncatulinoides* and by curves of variation in percentage of the >74μ fraction. Text-figure 2 shows these curves in two cores, A180-73 and A180-74.

The cores shown in text-figure 6 have been described by Ericson *et al.* (1956). Core P-136, obtained by Dr. P. W. Piggot, has been described and the distortion discussed by Cushman (1941), Piggot and Urry (1942), and Urry (1948).

RAPID METHOD OF FORAMINIFERAL ANALYSIS

Briefly, the procedure in the study of the foraminifera is as follows: Samples of about 5 grams dry weight are taken at suitable intervals. These are dried, weighed, and washed on a 74μ sieve. The coarse fraction is weighed, and its weight is reduced to a percentage of the original sample weight.

In sediments of normal particle-by-particle deposition, the >74μ fraction is largely composed of the tests of planktonic foraminifera. Consequently, the percentage of the coarse fraction tends to vary inversely as the rate of sediment accumulation, since an abundant supply of fine mineral particles will both increase the rate of accumulation and at the same time decrease, by dilution, the concentration of tests of planktonic foraminifera.

For micropaleontological analysis, a quantity of the coarse fraction sufficient to cover a microscope tray of 50 sq. cm. area is taken. The significant planktonic species are noted with a binocular microscope. Their frequencies in the sample are graded according to the following scale: Rare, 1 to 5 tests per tray; frequent, 6 to 10; common, 11 to 24; abundant, 25 to 100; very abundant, more than 100 tests.

The species of most significance as climatic indicators are: *Globorotalia menardii* (d'Orbigny), *Globorotalia truncatulinoides* (d'Orbigny), and *Globigerina inflata* d'Orbigny. The Recent layer contains *Globorotalia menardii* in abundance. The other two species are absent or poorly represented. In the underlying layer, the relationship is reversed. Tables giving frequencies of these and other planktonic foraminifera in cores A172-6, A179-4, and A180-73 have been published by Ericson and Wollin (1956), and the species that are believed to be indicative of cold and warm water are also discussed.

In drawing the climatic curves, it is assumed that the species in the top sample are adapted to the present climate. This present assemblage is taken as a standard with which assemblages lower in the core are compared. In many cores, *Globorotalia menardii* is somewhat more dominant about halfway down in the Recent zone than it is in the top sample. This is taken to indicate that the climate was a trifle warmer at that time than it is now. Text-figure 3 shows climatic curves based on the rapid method, together with curves of paleotemperatures for comparison. It is evident that there are various discrepancies between the two kinds of curves.

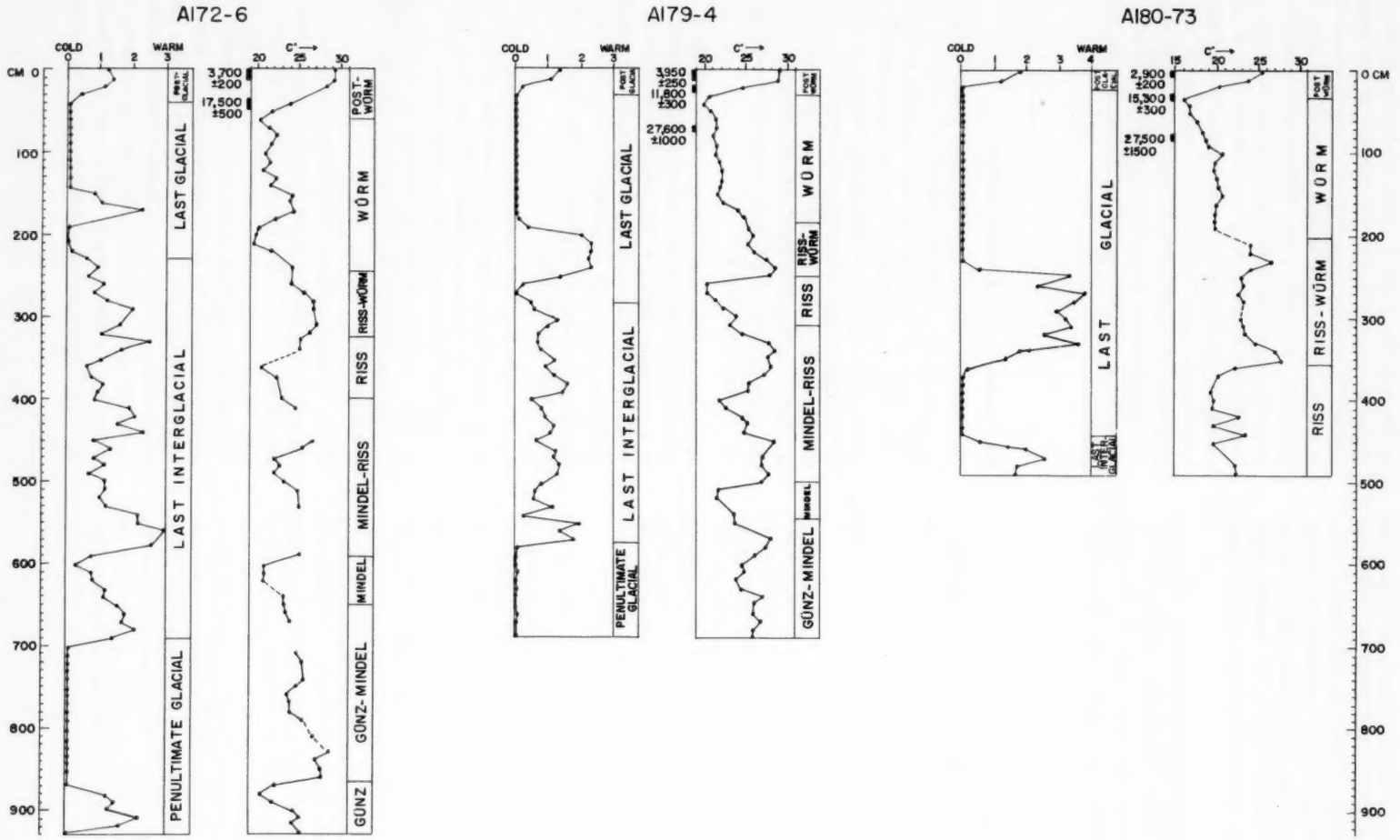
THE FREQUENCY-TO-WEIGHT-RATIO METHOD

The need of a more sensitive method was clear, but in view of the enormous amount of material (over 1000 cores) to be studied, it was desirable to develop a relatively rapid method. The method generally employed, that is, determination of percentages of species in the total number of tests in the sample, was prohibitively time-consuming and to some extent wasteful, in that it necessarily involved counting all species, even though some of the most abundant are of little or no climatic significance.

It seemed at this point that a possible substitute for percentages might be the ratio of the number of tests of a particular species to the weight of material in the >74μ fraction. This would give a plottable number that would be essentially equivalent to the percentage of the species in the total number of tests. Such a method has several advantages:

1) It results in a very great saving of time.
2) It makes it possible to plot variations in the abundance of particular climatically sensitive species without the necessity of counting others.
3) This, in turn, makes it possible to count larger samples, thereby increasing the statistical validity of the data.

If the washed material obtained as previously described is too abundant to just cover a microscope tray of 50 sq. cm., it is split or quartered with the device described by Parker (1948). The fraction taken for analysis is weighed on an analytical balance to the nearest milligram. To facilitate examination, immature forms are removed by screening on a 250μ sieve, which retains all mature specimens of the *Globorotalia menardii* group, *Globorotalia truncatulinoides,* and *Globigerina inflata,* species that appear to be particularly good indicators of climate.



TEXT-FIGURE 4

Comparison of climatic curves derived from variations in the frequency of *Globorotalia menardii* with oxygen-isotope paleotemperature curves. In each pair of curves, the curve to the right shows the isotopic temperatures obtained from *Globigerinoides sacculifer*, with the Pleistocene chronology as interpreted by Emiliani (1955). The curves to the left are based on the ratios of the numbers of *Globorotalia menardii* to the weights of the $> 74\mu$ fractions. Between each pair of curves, radiocarbon dates in years B.P., according to Suess (1956), are given, with the blacked-out zone indicating the range of the sample.

Specimens of the particular species chosen for analysis are counted, and the ratio of the number of tests to the weight of the $>74\mu$ fraction in milligrams is taken. This ratio, which may be called the "frequency" of the species, is then an index of its productivity as compared with the productivity of the total population.

Counts of *Globorotalia truncatulinoides, Globorotalia scitula, Globigerina inflata, Pulleniatina obliquiloculata,* and *Globigerinella aequilateralis* indicate that the *Globorotalia menardii* group is the most sensitive climatic indicator. The curves in text-figure 4 show variations in frequency of the *Globorotalia menardii* group. This group, which includes three subspecies, was chosen because it characterizes certain well-defined faunal zones that are widespread in the North Atlantic, Caribbean, and Gulf of Mexico. In addition, the frequency is highly variable from sample to sample, which suggests that the group is especially sensitive to changes in the environment. In the cores discussed here, the number of specimens counted varies from zero to over 2000.

In our use of the term "*Globorotalia menardii* group" we are following Phleger, Parker, and Peirson (1953), who recognized intergradation between *Globorotalia menardii, Globorotalia tumida,* and a third form in which the final chamber is narrow and sharply bent toward the ventral side. This is without doubt the form described by Koch (1923) as *Pulvinulina tumida* Brady var. *flexuosa,* from the "Jungtertiär" of Java. Since we have not found it in the Recent zone in any core from the North Atlantic, Caribbean, or Gulf of Mexico, it is probably extinct, at least in these waters. It occurs in great abundance, however, in the "warm" zone, which we tentatively correlate with Zeuner's (1954) warm interstadial of last glaciation. Because of intergradation between these three forms, we have concluded that they should be reduced to the rank of subspecies (Ericson and Wollin, 1956). We agree with Phleger, Parker, and Peirson that lumping the three forms, particularly when they occur lower down in the cores, is almost unavoidable, because of intergradation. In order to make the counts consistent throughout the cores, *Globorotalia menardii* and *Globorotalia tumida* have been counted together in the Recent zone.

Tables 2, 3, and 4 give counts of specimens of the *Globorotalia menardii* group, the weights of the samples in milligrams, and their ratios, or the frequencies of the *Globorotalia menardii* group in the total populations. Text-figure 4 shows curves of frequencies in the three cores, and curves of paleotemperatures drawn by Emiliani (1955) on the basis of oxygen-isotope measurements on the tests of *Globigerinoides sacculifer* (H. B. Brady).

Several well-defined zones in the frequency curves are evident. Below the Recent layer there is a zone in which the *Globorotalia menardii* group is absent or rare. In the next zone below, the group is abundant, particularly the subspecies *Globorotalia menardii flexuosa.* This zone characterized by *Globorotalia menardii flexuosa* is present in cores from the Gulf of Mexico and in many cores from widely scattered stations in the North Atlantic. Thus the evidence that this zone is equivalent in the three cores is good.

Beneath the *Globorotalia menardii flexuosa* zone is another layer in which the *Globorotalia menardii* group is absent. In these cores from low-latitude stations, this layer is relatively thin. Farther north we have found it to be thicker, probably because of more rapid accumulation of the fine terrigenous fraction.

Below this short "cold" interval there is a rather thick zone in which the *Globorotalia menardii* group is consistently abundant, although the frequency varies markedly. In general, the frequency oscillations correlate satisfactorily with the oxygen-isotope temperatures. Core A180-73 ends in this zone. The two cores from the Caribbean penetrate to another zone in which the *Globorotalia menardii* group is rare or absent. Here we encounter a serious disagreement between the frequency curves and the isotopic paleotemperatures. Only core A172-6 enters another lower zone in which the *Globorotalia menardii* group is again very abundant.

DISCUSSION AND CONCLUSIONS

Comparison of the curves shows close agreement between variations in frequency of the *Globorotalia menardii* group and paleotemperatures throughout core A180-73, and down to centimeter 700 and centimeter 580 in cores A172-6 and A173-4, respectively. It is hardly likely that this is a result of mere coincidence. However, lower down in cores A172-6 and A173-4 there is marked disagreement between the results of the two methods. Several possible explanations for this disagreement should be considered. The species group might not have gained access to the Atlantic until its appearance in abundance at centimeter 580 in core A179-4. This explanation fails because the group does occur abundantly in the lowest part of core A172-6, and, furthermore, rare specimens occur in some samples in the "cold" zone. Solution of

TABLE 2

THE NUMBERS OF *Globorotalia menardii*, THE WEIGHTS OF THE $>74\mu$ FRACTIONS, AND THE RATIOS OF THE NUMBERS OF *Globorotalia menardii* TO THE WEIGHTS OF THE $>74\mu$ FRACTIONS IN CORE A172–6

Sample position from top in cm.	Number of *Globorotalia menardii*	Weight of fraction 74μ in mg.	Ratio	Sample position from top in cm.	Number of *Globorotalia menardii*	Weight of fraction 74μ in mg.	Ratio
Top	829	694	1.2	480	597	530	1.1
10	904	683	1.3	490	174	307	0.6
20	1147	1015	1.1	500	442	387	1.1
30	322	897	0.4	510	397	354	1.1
40	22	846	0.0	520	462	481	1.0
50	3	520	0.0	530	483	442	1.1
60	3	309	0.0	540	711	338	2.1
70	0	368	0.0	550	342	165	2.1
80	0	421	0.0	560	80	27	3.0
90	0	164	0.0	570		90% broken	
100	0	738	0.0	580	2078	821	2.5
110	0	76	0.0	590	439	613	0.7
120	0	794	0.0	600	115	545	0.2
130	0	365	0.0	610	217	338	0.6
140	1	495	0.0	620	114	187	0.6
150	606	801	0.8	630	429	375	1.1
160	375	391	1.0	640	510	518	1.0
170	1188	586	2.0	650	713	516	1.4
180	631	526	1.2	660	676	413	1.6
190	0	374	0.0	670	683	442	1.5
200	2	408	0.0	680	353	172	2.1
210	0	205	0.0	690	428	325	1.3
220	30	218	0.1	700	0	1008	0.0
230	147	260	0.6	710	2	7339	0.0
240	387	418	0.9	720	0	4263	0.0
250	222	354	0.6	730	0	4937	0.0
260	554	503	1.1	740	0	3610	0.0
270	238	316	0.8	750	0	7912	0.0
280	599	407	1.2	760	0	4440	0.0
290	795	391	2.0	770	0	8499	0.0
300		90% broken		780	0	6420	0.0
310	962	637	1.5	790	45	1868	0.0
320	421	412	1.0	800	0	3252	0.0
330	1445	576	2.5	810	0	4111	0.0
340	995	636	1.6	820	0	2154	0.0
350	277	290	1.0	830	0	3421	0.0
360	144	243	0.6	840	0	1235	0.0
370	157	227	0.7	850	0	4890	0.0
380	382	350	1.1	860	0	5815	0.0
390	176	193	0.9	870	0	2181	0.0
400	314	377	0.8	880	1580	1678	0.9
410	1283	727	1.8	890	2000	1405	1.4
420	984	492	2.0	900	1910	1566	1.2
430	623	428	1.5	910	2290	1104	2.1
440	964	417	2.3	920	3910	2686	1.5
450	350	509	0.7	930	0	1073	0.0
460	473	369	1.3	935	0	797	0.0
470	217	290	0.8				

TABLE 3

THE NUMBERS OF *Globorotalia menardii*, THE WEIGHTS OF THE $>74\mu$ FRACTIONS, AND THE RATIOS OF THE NUMBERS OF *Globorotalia menardii* TO THE WEIGHTS OF THE $>74\mu$ FRACTIONS IN CORE A179–4

Sample position from top in cm.	Number of *Globorotalia menardii*	Weight of fraction 74μ in mg.	Ratio	Sample position from top in cm.	Number of *Globorotalia menardii*	Weight of fraction 74μ in mg.	Ratio
Top	572	443	1.3	350	544	400	1.4
10	558	490	1.1	360	1217	1287	0.9
20	61	293	0.2	370	745	630	1.2
30	1	789	0.0	380	1183	760	1.6
40	0	940	0.0	390	738	500	1.5
50	2	842	0.0	400	329	650	0.5
60	0	752	0.0	410	434	575	0.8
70	0	932	0.0	420	265	307	0.9
80	0	891	0.0	430	423	360	1.2
90	0	910	0.0	440	644	600	1.1
100	0	950	0.0	450	328	574	0.6
110	0	896	0.0	460	579	438	1.3
120	0	841	0.0	470	404	343	1.2
130	0	778	0.0	480	600	438	1.4
140	2	983	0.0	490	687	514	1.3
150	0	815	0.0	500	430	574	0.8
160	0	911	0.0	510	203	338	0.6
170	8	835	0.0	520	223	396	0.6
180	67	527	0.1	530	788	666	1.2
190	321	755	0.4	540	57	337	0.2
200	1150	584	2.0	550	1204	633	1.9
210	790	342	2.3	560	743	586	1.3
220	675	295	2.3	570	571	321	1.8
230	895	406	2.2	580	17	425	0.0
240	717	306	2.3	590	5	364	0.0
250	1048	740	1.4	600	5	525	0.0
260	182	786	0.2	610	51	515	0.1
270	8	461	0.0	620	8	531	0.0
280	293	563	0.5	630	39	588	0.1
290	335	549	0.6	640	15	425	0.0
300	957	691	1.4	650	9	430	0.0
310	606	604	1.0	660	68	800	0.1
320	539	795	0.7	670	22	485	0.0
330	324	480	0.7	680	6	692	0.0
340	466	550	0.8	690	15	664	0.0

TABLE 4

THE NUMBERS OF *Globorotalia menardii*, THE WEIGHTS OF THE >74μ FRACTIONS, AND THE RATIOS OF THE NUMBERS OF *Globorotalia menardii* TO THE WEIGHTS OF THE >74μ FRACTIONS IN CORE A180–73

Sample position from top in cm.	Number of *Globorotalia menardii*	Weight of fraction 74μ in mg.	Ratio	Sample position from top in cm.	Number of *Globorotalia menardii*	Weight of fraction 74μ in mg.	Ratio
Top	850	504	1.7	250	847	250	3.4
10	333	273	1.2	260	773	330	2.3
20	0	641	0.0	270	665	176	3.8
30	1	573	0.0	280	873	255	3.4
40	0	712	0.0	290	1008	343	2.9
50	0	653	0.0	300	505	159	3.2
60	0	492	0.0	310	935	277	3.4
70	0	581	0.0	320	303	123	2.5
80	0	679	0.0	330	427	119	3.6
90	0	791	0.0	340	298	169	1.8
100	0	648	0.0	350	210	160	1.3
110	0	663	0.0	360	24	116	0.2
120	0	692	0.0	370	16	195	0.1
130	0	712	0.0	380	0	249	0.0
140	0	721	0.0	390	1	294	0.0
150	0	819	0.0	400	0	312	0.0
160	0	831	0.0	410	1	418	0.0
170	0	765	0.0	420	0	391	0.0
180	0	684	0.0	430	3	452	0.0
190	1	641	0.0	440	8	483	0.0
200	0	719	0.0	450	126	224	0.6
210	0	732	0.0	460	402	200	2.0
220	4	686	0.0	470	358	139	2.6
230	28	451	0.1	480	207	121	1.7
240	164	299	0.5	490	319	186	1.7

the tests after deposition is not likely. The tests of other species in this zone are well preserved, and, in addition, we know from experience with other cores that the tests of *Globorotalia menardii* are much less easily destroyed by solution than those of other species. Conceivably, some alteration in the temperature tolerance of a species might take place within the time-intervals represented by these cores. However, the high-latitude species *Globigerina inflata* d'Orbigny is abundant in this same zone. It seems improbable that the temperature tolerances of two species changed at about the same time. This suggests that the surface waters of the Caribbean were actually cool during the time when this zone was deposited.

An alternative explanation is worth mentioning. Karpachena and Rozen (in G. V. Chilingar, 1955) believe that they have found experimental evidence of exchange of oxygen between calcium carbonate and water. However, other Russian investigators, Brodskiy and Lunenok-Burmakina (in Chilingar, 1953) have concluded that although some exchange does take place it is too small to invalidate the method. They examined the isotopic composition of $CaCO_3$ after exchange with heavy-oxygen water at the end of sixty days and found an exchange of only 3.5%. However, it may be that the time involved is an important factor. After more than 60,000 years, even under natural conditions the amount of exchange might lead to serious errors.

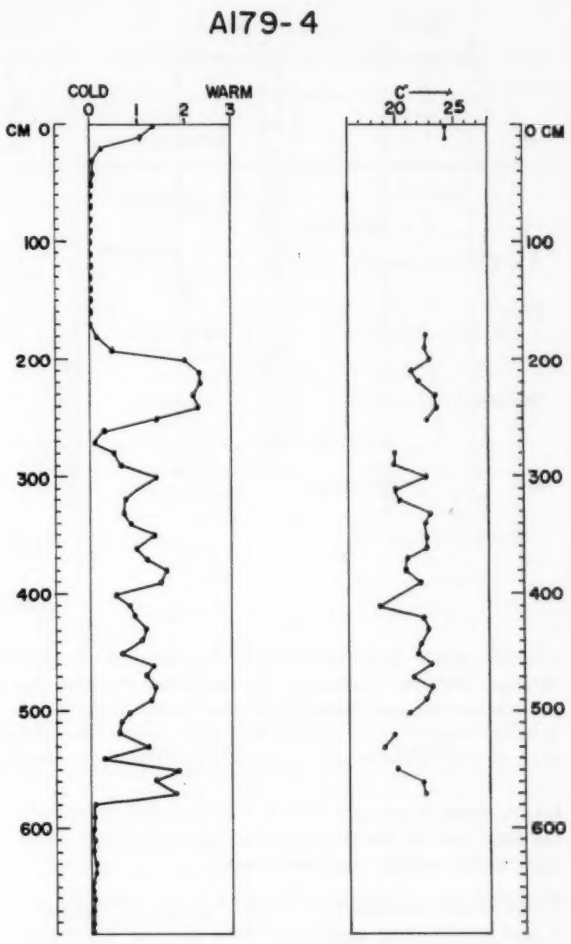
Although *Globorotalia menardii* is not a species suitable for continuous curves of isotopic paleotemperatures, since it is rare to absent in certain zones, it is interesting to compare the frequency curve of this species with the paleotemperatures registered by it in those zones in which it is abundant. Text-figure 5 shows that there is close correlation between the two curves in core A179-4.

Emiliani (1955) has made a tentative correlation of paleotemperature variations and the subdivisions of the Pleistocene as worked out by glacial geologists. It seems to us that another interpretation is worth considering. In text-figures 3 and 4, Emiliani's correlation with Pleistocene events and our correlation are compared.

It has seemed to us that the *Globorotalia menardii flexuosa* zone, or the first warm zone below the top, was too thin to represent the last interglacial age. On the other hand, until relatively recently there was no evidence that there was, within the Würm or last glacial age, an interstadial that had a climate as mild as that indicated by both the foraminifera and the paleotemperatures in the cores. However, according to Zeuner (1954), it seems that there is indeed evidence of such an interstadial. In the conclusion of his paper, he says: "A very remarkable feature is now emerging. The interstadial between the first and second phases of the last glaciation was fully temperate. Though shorter than the last interglacial, it was quite as temperate as the Postglacial." Table 5 shows the relationship between the sequence of late Pleistocene climates and sea levels according to Zeuner (1954).

Absence of evidence of the interstadial between the second and third phases in the frequency curve of the *Globorotalia menardii* group is not difficult to explain. If water temperature at that time did not reach a certain threshold value, no appreciable proliferation of the group would be likely to occur. On the other hand, if, as Zeuner believes, there was an earlier interstadial during which the climate was as warm as at present or even slightly warmer, marked proliferation of the *Globorotalia menardii* group would be most expectable. The absence of any such evidence would be difficult to explain, particularly in view of the rapid response of the group to the postglacial amelioration, as shown by comparison of the paleotemperature curves with the frequency curves.

We differ from Emiliani also in assigning to the last interglacial age the entire section in which the *Globorotalia menardii* group is abundant or very abundant. Climatic variations within this zone are indicated by the frequency curves and the paleotemperatures, but

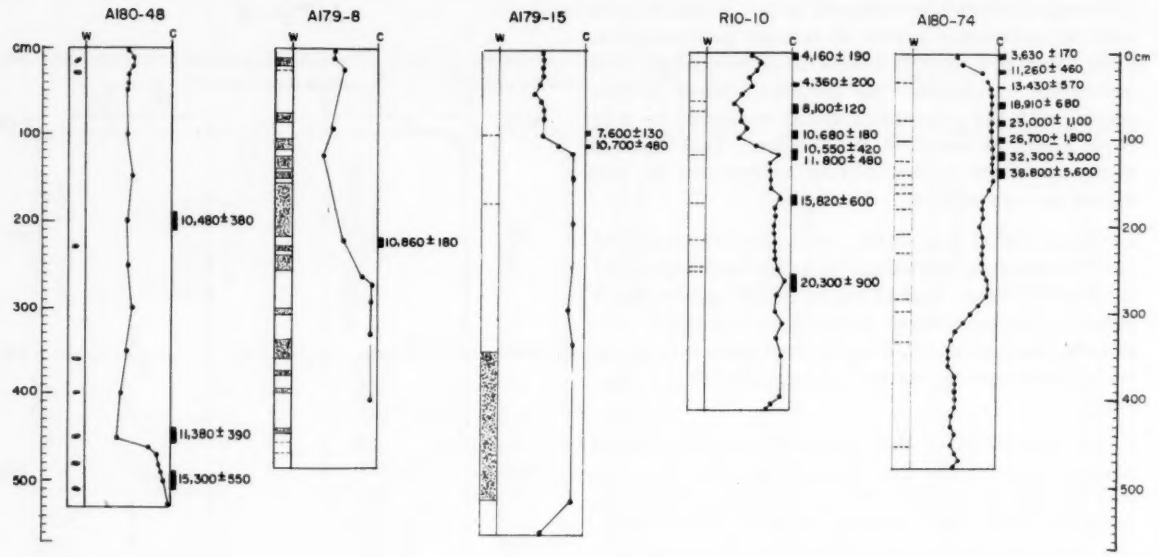


TEXT-FIGURE 5

To the left, a climatic curve based on the ratios of the numbers of *Globorotalia menardii* to the weights of the $> 74\mu$ fractions, and to the right the isotopic temperatures obtained from the same species.

according to the frequency curves there was no time when conditions were as unfavorable to the growth of the *Globorotalia menardii* group as they were during that part of the curve which we believe to correspond to the last glacial age.

Such a time of unfavorable conditions is indicated by the frequency curves lower down in cores A172-6 and A179-4. We take this to represent the penultimate glaciation. In the lower 50 centimeters of core A172-6 there is a zone with high frequency of the *Globorotalia menardii* group. This is tentatively included by us in the penultimate glaciation. Until a longer core is



TEXT-FIGURE 6

Climatic curves, radiocarbon dates in years B.P., according to Broecker *et al.* (1956), and the lithology of five cores obtained from the Caribbean, the equatorial Atlantic, and lat. 41° N. The curves are based on the relative numbers of warm-water and cold-water planktonic foraminifera. **W** indicates a relatively warm climate, and **C** a relatively cold climate. A blacked-out zone to the left of a radiocarbon date shows the range of the sample. A dashed line indicates change in color of the sediment, and a dotted zone indicates calcareous sand and silt.

taken, there is no way to tell whether this represents the final part of the penultimate interglacial age or an interstadial within the penultimate glacial age.

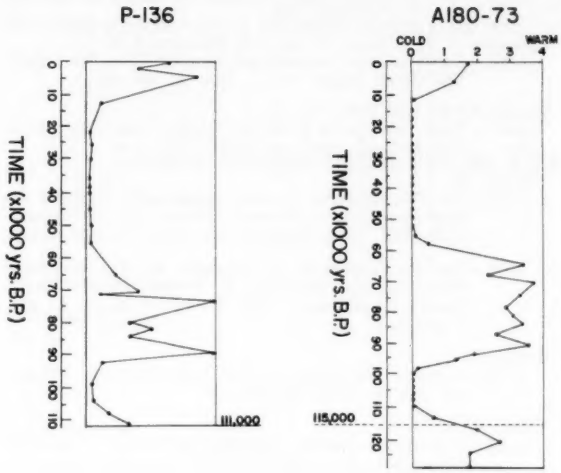
From Suess's radiocarbon dates, shown in text-figures 3 and 4, Emiliani concluded that the last glaciation ended 16,500 years ago. Ericson *et al.* (1956), on evidence from radiocarbon dates reported by Broeker *et al.* (1956), came to the conclusion that a more reliable date for the end of the last glaciation is 11,000 years B.P. The cores and the dates on which these conclusions were based are shown in text-figure 6.

Text-figure 7 shows an interesting relationship. One curve shows the results of Cushman's (1941) counts of *Globorotalia menardii* in core P-136, from the Caribbean. The other curve is based on our frequency-to-weight ratios of the *Globorotalia menardii* group in core A180-73, from the equatorial Atlantic. The correlation is striking. The significance of this relationship is that core P-136 was dated by means of the ionium method, by Urry (1948). The date of the bottom of core P-136 was, according to Urry, 111,000 years B.P. This point in the core, we believe, marks the beginning of the last glacial stage, on the evidence of Cushman's curve of *Globorotalia menardii* frequency.

In the same figure, the frequency of the *Globorotalia menardii* group is plotted against a time-scale based on the micropaleontological and lithologic investigation of over 200 cores, and on more than forty radiocarbon dates of selected samples from selected cores. How this time-scale was derived will be described in detail in a paper which is in preparation. We merely want to point out here that there is correlation not only between our time-scale and the frequency of *Globorotalia menardii*, but also between our time-scale and Urry's ionium dating.

ACKNOWLEDGMENTS

The authors acknowlege with gratitude the cooperation of Cesare Emiliani, Hans E. Suess, J. Lawrence Kulp and Wallace S. Broecker in the study of the cores. We are greatly indebted to W. Maurice Ewing, Director of Lamont Geological Observatory, for obtaining cores and for his generous support of the work. We are grateful to Bruce C. Heezen, who was responsible for taking the equatorial cores, among others, and who kindly advised us regarding the topography. We are thankful to Janet Wollin for valuable work in the laboratory, to John Gorsline for



TEXT-FIGURE 7

To the left, variation in the frequency of *Globorotalia menardii* in core P-136 according to Cushman (1941), plotted on a time-scale based on dates determined by Urry (1948) by the ionium method. To the right, variations in the frequency of *Globorotalia menardii* in core A180-73; the curve is based on the ratios of the numbers of specimens to the weights of the $> 74\mu$ fractions, plotted against a time-scale based on micropaleontological and lithologic investigation of over 200 cores and on about forty radiocarbon dates of selected samples from selected cores. Core P-136 was obtained from the Caribbean by Dr. C. S. Piggot, and core A180-73 from the equatorial Atlantic by Lamont Geological Observatory.

TABLE 5

PLEISTOCENE CLIMATES AND SEA-LEVELS*

GENERAL NOMENCLATURE		SEA LEVELS
Postglacial temperate		Present
Last glacial age	Phase 3 cool	−30 meters (approx.)
	Interstadial less cool	−10 meters (approx.)
	Phase 2 cool	−70 meters (approx.)
	Interstadial temperate	+3 meters
	Phase 1 cool	−100 meters (approx.)
Last interglacial age	Temperate	+7.5 meters
	Cool	Lower
	Temperate	+18 meters
Penultimate glacial age		−200 meters (approx.)

* (Modified from Zeuner, 1954, Eiszeitalter und Gegenwart, vol. 4/5, pp. 98-105.)

drafting the illustrations, and to R. E. Heningham for photographic work.

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Lamont Geological Observatory Contribution No. 190.

BIBLIOGRAPHY

BROECKER, W. C., KULP, J. L., AND TUCEK, C. S.
[MS.] *Lamont natural radiocarbon measurements; III.* (In press, 1956.)

CHILINGAR, G. V.
1955 – *Is O^{18}:O^{16} ratio in carbonate rocks an accurate geologic thermometer? Brief review of Russian literature.* Amer. Assoc. Petr. Geol., Bull., vol. 39, no. 11, p. 2349.

CUSHMAN, J. A.
1941 – *A study of the foraminifera contained in cores from the Bartlett Deep.* Amer. Jour. Sci., vol. 239, pp. 128-147.

CUSHMAN, J. A., AND HENBEST, L. G.
1940 – *Geology and biology of North Atlantic deep-sea cores between Newfoundland and Ireland; Part 2 — Foraminifera.* U. S. Geol. Survey, Prof. Paper no. 196-A, pp. 35-56.

EMILIANI, C.
1955 – *Pleistocene temperatures.* Jour. Geol., vol. 63, no. 6, pp. 538-577.

ERICSON, D. B., BROECKER, W. C., KULP, J. L., AND WOLLIN, G.
[MS.] *Late-Pleistocene climates and deep-sea sediments.* (In press, 1956.)

ERICSON, D. B., EWING, M. AND HEEZEN, B. C.
1952 – *Turbidity currents and sediments in the North Atlantic.* Amer. Assoc. Petr. Geol., Bull., vol. 36, no. 3, pp. 489-511.

ERICSON, D. B., EWING, M., HEEZEN, B. C., AND WOLLIN, G.
1955 – *Sediment deposition in deep Atlantic.* In: POLDERVAART, A., *Crust of the earth (a symposium).* Geol. Soc. Amer., Spec. Paper no. 62, pp. 205-219, pls. 1-2, text-figs. 1-3.

ERICSON, D. B., AND WOLLIN, G.
1956 – *Correlation of six cores from the equatorial Atlantic and the Caribbean.* Deep-Sea Res., vol. 3, no. 2, pp. 104-125.

EWING, M., ERICSON, D. B., HEEZEN, B. C., WORZEL, J. L., AND WOLLIN, G.
1954 – *Exploration of the deep-sea floor.* Quaternaria, vol. 1, pp. 145-168.

KOCH, R.
1923 – *Die jungtertiäre Foraminiferenfauna von Kabu (Res. Surabaja Java).* Eclogae Geol. Helv., vol. 18 (1923-1924), no. 2, p. 357.

KULLENBERG, B.
1944 – *Kolvlodet.* Geol. Fören. Stockholm, Förhandl., vol. 66, p. 501.

1947 – *The piston core sampler.* Sweden, Hydr.-Biol. Komm., Skr., ser. 3 (Hydr.), vol. 1, no. 1.

1955 – *Deep-sea coring.* Swedish Deep-Sea Exped. 1947-1948, Repts., vol. 4, fasc. 1, pp. 36-96.

OVEY, C. D.
1950 – *On the interpretation of climatic variations as revealed by a study of samples from an equatorial Atlantic deep-sea core.* In: *Centenary symposium on climatic change.* Roy. Meteorol. Soc., Centenary Proc., pp. 211-215.

PARKER, F. L.
1948 – *Foraminifera of the Continental Shelf from the Gulf of Maine to Maryland.* Harvard, Mus. Comp. Zool., Bull., vol. 100, no. 2, pp. 213-241.

PHLEGER, F. B
1939 – *Foraminifera of submarine cores from the continental slope.* Geol. Soc. Amer., Bull., vol. 50, pp. 1395-1422, pls. 1-3, text-figs. 1-4, tables 1-3.

1942 – *Foraminifera of submarine cores from the continental slope; Part 2.* Ibid., vol. 53, no. 7, pp. 1073-1098, pls., 1-3, text-figs. 1-6.

PHLEGER, F. B, PARKER, F. L., AND PEIRSON, J. F.
1953 – *North Atlantic foraminifera.* Swedish Deep-Sea Exped. 1947-1948, Repts., vol. 7, fasc. 1, 122 pp.

PIGGOT, C. S., AND URRY, W. D.
1942 – *Time relations in ocean sediments.* Geol. Soc. Amer., Bull., vol. 53, no. 8, pp. 1187-1210.

SCHOTT, W.
1935 – *Die Foraminiferen in dem aequatorialen Teil des Atlantischen Ozeans.* Deutsch. Atlant. Exped. "Meteor" 1925-1927, Wiss. Ergebn., vol., 3, pt. 3, pp. 43-134.

1952 – *On the sequence of deposits in the equatorial Atlantic Ocean.* Göteborgs K. Vetensk. — och Vitterh. Samh., Handl., sec. 6, ser. B., vol. 6, no. 2, 15 pp, 3 text-figs.

SUESS, H. E.
1956 – *Absolute chronology of the last glaciation.* Science, vol. 123, no. 3192, pp. 355-357.

UREY, H. C.
1947 – *The thermodynamic properties of isotopic substances.* Chem. Soc., Jour., pp. 562-581.

URRY, W. D.
1948 – *Radioactivity of ocean sediments; VII — Rate of deposition of deep-sea sediments.* Jour. Marine Res., vol. 7, no. 3, pp. 618-633.

ZEUNER, F. E.
1954 – *Riss or Würm?* Eiszeitalter und Gegenwart, vol. 4/5, pp. 98-103.

ABSTRACT: *From a study of the variations of the Lingulinae occurring at successive horizons in the Lias, an attempt is made to unravel the history of the species plexus. The taxonomy of the chief species is discussed and the zonal significance of the main variants assessed, with the aid of a diagram of the plexus.*

Some Lingulinae from the Lias of England

TOM BARNARD
University College
London

INTRODUCTION

In 1950 (Barnard, 1950*a*), the writer mentioned some of the difficulties encountered when studying the systematics of Lingulinae from the Lias. At the time, he felt that many of these difficulties resulted from the study of specimens from only a few isolated localities and disconnected sections.

Macfadyen (1941, p. 52) has suggested that a close study of the forms of *Lingulina tenera* Bornemann would be of interest and might prove of value for zonal purposes. For a considerable time, the present writer regarded the varieties of that species as having little or no stratigraphic significance. This view was based on a study of specimens from scattered localities, which did not give a continuous stratigraphic column. The writer has now had the good fortune to be allowed to examine a complete succession extending from the pre-*planorbis* beds of the Lower Lias, through the Middle Lias, to the top of the Upper Lias, perfectly represented in continuous cores from an exploratory boring by the Geological Survey at Stowell Park, Gloucestershire. This section has provided extremely good material for research, which, together with material from several other localities, has shown that the author's doubts on this point were unfounded and that Macfadyen's suggestion was correct.

SYSTEMATIC DESCRIPTIONS

Genus **Lingulina** d'Orbigny, 1826

Genotype: Lingulina carinata d'Orbigny, 1826.

Cushman (1940, p. 201) states: "Test in the early stages, at least in the microspheric form, planispiral, later chambers in a rectilinear series." A study of many specimens from the Lias, of both microspheric and megalospheric generations, has failed to reveal any initial coiled stage. All specimens begin with an almost spherical proloculum followed by a rectilinear series of chambers (see Plate 1, figures 1 and 2). The different species may be smooth or with ribbed ornament.

A. SMOOTH FORMS

Lingulina esseyana Deecke
Plate 1, figures 3a-b, 4

Lingulina carinata d'Orbigny. – JONES AND PARKER, 1860 (part), Geol. Soc. London, Quart. Jour., vol. 16, p. 457, pl. 19, figs. 13-14 (*non* fig. 15). – BRADY, 1867, Somersetsh. Archaeol. Nat. Hist. Soc., Proc., vol. 13, p. 107, pl. 1, fig. 10a.

Lingulina esseyana DEECKE, 1886, Soc. Emul. Montbéliard, Mém., ser. 3, vol. 16, p. 312.

Lingulina ovalis TERQUEM AND BERTHELIN, 1875 (*non* SCHWAGER, 1865), Soc. Géol. France, Mém., ser. 2, vol. 10, no. 3, p. 23, pl. 1, fig. 27a-b. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 63, pl. 6, fig. 13. – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 106, pt. 1, p. 28, pl. 1, fig. 5.

Description: Test compressed, slightly biconvex, composed of four to eight chambers. Both generations have a globular proloculum. The first three chambers usually show a rapid increase in breadth, so that the initial part of the test has strongly divergent sides. Sometimes, however, the early chambers show little increase in breadth, so that at this stage of growth the test is parallel-sided; this stage is then followed by a rapid increase in the breadth of the chambers. In forms with divergent sides in the early stage, succeeding chambers are about half as high as broad; the sides show little divergence, either being almost parallel-sided or even tapering toward the aperture. In some specimens a median sinus of varying depth occurs on the

chambers, and swollen lateral lobes develop on each side of it. The terminal aperture is slit-like, sometimes with a slightly projecting neck or rim.

Depository: British Museum (Natural History), London: nos. P.40497, P.40549; Barnard collection: nos. L.11 (i-ii), L.12 (i).

Horizon: Upper Lias, *serpentinum* zone.

Locality: Byfield, Northamptonshire, England.

Lingulina laevissima (Terquem)
Plate 1, figure 5a-b

Frondicularia laevissima TERQUEM, 1866, Sixième mémoire sur les foraminifères du Lias, p. 481, pl. 19, fig. 19a-b.
Lingulina laevissima (Terquem). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 62, pl. 6, fig. 11. – MACFADYEN, 1941, Roy. Soc. London, Philos. Trans., ser. B, vol. 231, p. 50, pl. 3, fig. 51a-b. – USBECK, 1952, Neues Jahrb. Geol. Pal., Abh., vol. 95, no. 3, p. 392, pl. 16, fig. 40.
Lingulina lanceolata (Haeusler). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 62, pl. 6, fig. 10. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 151, pl. 2B, fig. 17.

Description: Test very narrow, compressed, smooth, composed of eight to ten chambers. A smooth globular proloculum is followed by a rectilinear series of chambers whose height increases rapidly to about three times the breadth. The breadth increases very slowly, and the sides of the test are almost parallel. The chambers are depressed, oval in shape, and are separated by constricted sutures. The sutures are slightly arcuate, convex toward the aperture. The central terminal aperture is slit-like and is flush with the end of the test, without projection or neck.

Depository: Geological Survey and Museum, London: no. Mik (M) 458005.

Horizon: Lower Lias, *angulatum* zone, *laqueus* subzone.

Locality: Sample from 1950-1960 feet in Geological Survey boring at Stowell Park, Northleach, Gloucestershire, England.

Remarks: These specimens are somewhat narrower than those figured by Terquem, Franke (1936, fig. 11) and Macfadyen; but Usbeck and Franke (1936, fig. 10) figure specimens that are almost identical. However, these two Lias forms may possibly be different species.

The occurrence of the smooth Lingulinae is sporadic, and they are often rare, so that any attempt at a study of their variation is difficult. As more material becomes available, it may be possible to show that *Lingulina laevissima, L. lanceolata,* and *L. cernua* represent the same long-ranging species, varying in shape from horizon to horizon, as is the case with so many species of lagenids.

PLATE 1

All figures approximately × 95

1 *Lingulina tenera* Bornemann
Megalospheric generation, showing the arrangement of the chambers.

2 *Lingulina tenera* Bornemann
Microspheric generation, showing the arrangement of the chambers.

3 *Lingulina esseyana* Deecke
a, side view, showing slight medial sulci; b, apertural view. Upper Lias; Byfield. Brit. Mus. (Nat. Hist.), no. P.40497.

4 *Lingulina esseyana* Deecke
Side view. Upper Lias; Byfield. Brit. Mus. (Nat. Hist.), no. P.40549.

5 *Lingulina laevissima* (Terquem)
a, side view; b, apertural view. Lower Lias, *angulatum* zone; Stowell Park, 1950-1960 feet. Geol. Survey and Mus., no. Mik (M) 458005.

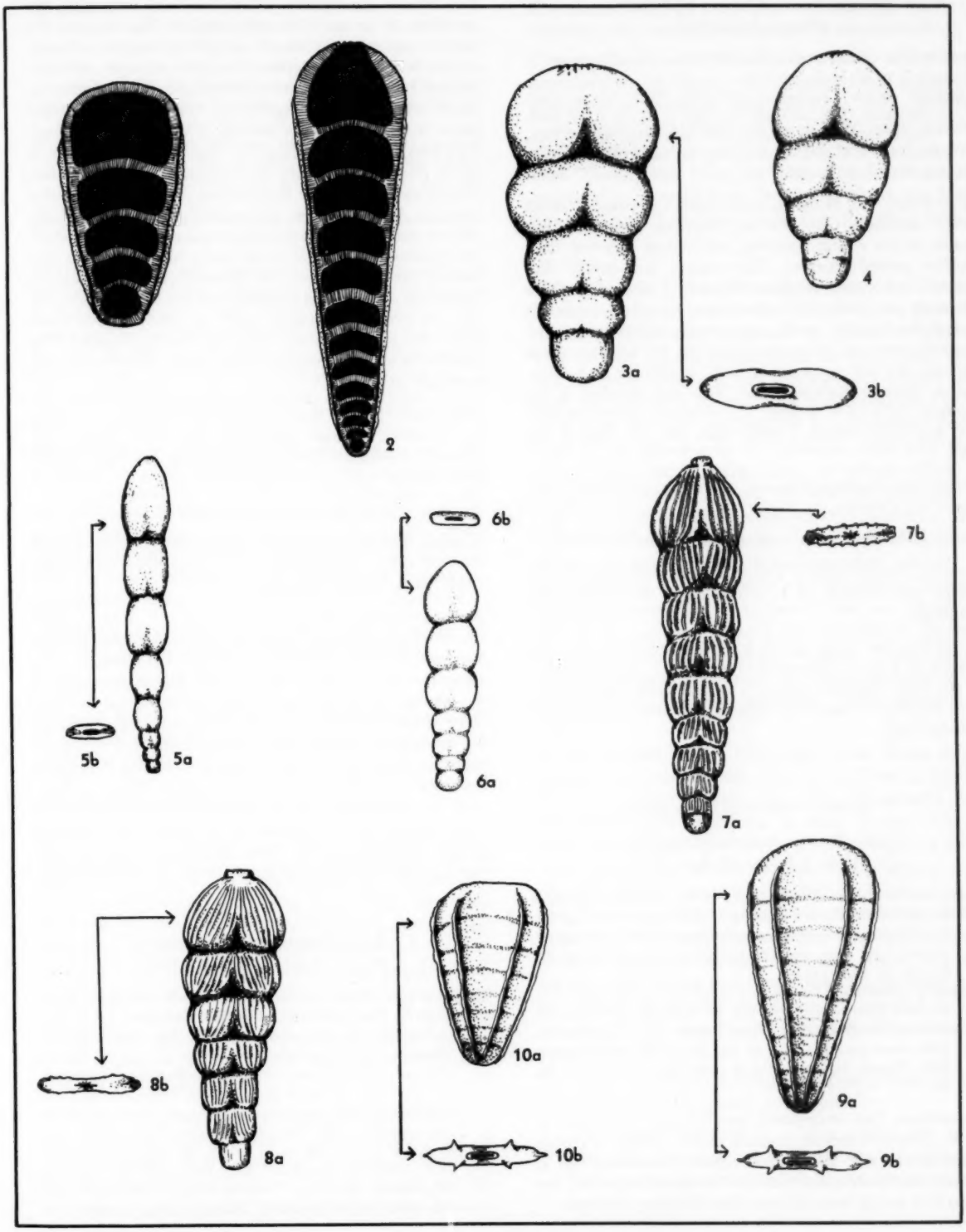
6 *Lingulina* cf. *cernua* (Berthelin)
a, side view; b, apertural view. Lower Lias, *planorbis* zone; Stowell Park, 2010-2020 feet. Geol. Survey and Mus., no. Mik (M) 458001.

7 *Lingulina nodosaria* (Terquem)
a, side view; b, apertural view. Upper Lias; Byfield. Barnard coll., no. L.1.

8 *Lingulina nodosaria* (Terquem)
a, side view; b, apertural view. Upper Lias; Byfield. Barnard coll., no. L.2.

9 *Lingulina tenera* Bornemann
Form B. a, side view; b, apertural view. Lower Lias, *bucklandi* zone; Stowell Park. Geol. Survey and Mus., no. Mik (M) 458003.

10 *Lingulina tenera* Bornemann
Form B, a juvenile specimen. a, side view; b, apertural view. Lower Lias, *bucklandi* zone; Stowell Park. Geol. Survey and Mus., no. Mik (M) 458004.


2
3a
3b
4
5a
5b
6a
6b
7a
7b
8a
8b
9a
9b
10a
10b

Lingulina cf. **cernua** (Berthelin)
Plate 1, figure 6a-b

Frondicularia cernua BERTHELIN, 1879, Rev. Mag. Zool., ser. 3, vol. 7, p. 32, pl. 1, figs. 7-8.
Lingulina cernua (Berthelin). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 61, pl. 6, fig. 8a-d. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 151, pl. 4, fig. 51; pl. 5, fig. 34; pl. 6, fig. 18; pl. 7, fig. 22.

Description: Test elongate, compressed, composed of about seven chambers. Only the megalospheric generation was found. It has a large spherical proloculum followed by a smaller second chamber. The sutures are deeply constricted and almost straight. The height of the chambers increases progressively. In the second chamber, the height is half the breadth; in the next two chambers, height and breadth are equal; in the two following, the height is about one and one-half times the breadth; finally, the end chamber is twice as high as broad. This end chamber is depressed and oval in section. The terminal aperture is central and oval, without a neck, flush with the wall of the test.

Depository: Geological Survey and Museum, London: no. Mik (M) 458001.

Horizon: Lower Lias, *planorbis* zone, *planorbis* subzone.

Locality: Sample from 2010-2020 feet in Geological Survey boring at Stowell Park, Northleach, Gloucestershire, England.

Remarks: The range given by Franke (1936) for this species is Lias β (Turneriton) to Lias δ (Spinatussch). If the form described above is in fact Berthelin's species, then its range is extended through the whole Lower and Middle Lias.

B. FORMS WITH RIBBED ORNAMENT

Lingulina nodosaria (Terquem)
Plate 1, figures 7a-b, 8a-b

Frondicularia nodosaria TERQUEM, 1870, Troisième mémoire sur les foraminifères du Système Oolithique, p. 217, pl. 22, figs. 25-30. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 155, pl. 12A, fig. 6; pl. 13, fig. 14; pl. 15A, fig. 21.
Lingulina nodosaria (Terquem). – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 106, pt. 1, p. 29, pl. 1, fig. 16.
Frondicularia hauffi FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 66, pl. 6, fig. 22. – PAYARD, 1947, Foram. Lias sup. détroit poitevin, p. 116, pl. 6, fig. 30.

Description: Test compressed, parallel-sided, composed of six to thirteen chambers (usually nine). There is a wide range in the size of the proloculum. Sometimes this is almost completely surrounded by the second chamber, but often it is nearly isolated from the following chambers. The sutures are slightly constricted, and sometimes the periphery of the test is strongly lobulate. The shape of the sutures varies from almost straight or slightly arcuate, convex toward the aperture, to quite strongly chevron-shaped. It is thus a matter of personal opinion whether to assign the species to *Lingulina* or *Frondicularia*. In some cases, the end chambers develop a strong median sinus, with lateral lobes on each side. The ornament consists of about fourteen to twenty fine striations. The proloculum may be either smooth or finely striate. There is considerable variation in the number, disposition and strength of the ribs or striae. Two chief variants occur, in one of which the striations are straight in the centre of the chamber, but toward the edge of the test become curved and closely follow the shape of the periphery; in the other variant, the ribs are strongly divergent from the aperture, and again follow the periphery more closely as it is approached. The aperture is slit-like, central, with a neck, which varies considerably in length.

Depository: British Museum (Natural History), London: no. P.40555; Barnard collection: nos. L.1 (i-xxv), L.2 (i-xviii); Geological Survey and Museum, London: no. Mik (M) 458002.

Horizon: Upper Lias, *serpentinum* zone.

Locality: Byfield, Northamptonshire (British Museum and Barnard coll.), and Stowell Park, Northleach, Gloucestershire (Geol. Survey and Museum).

Remarks: Bartenstein and Brand (1937, p. 109) suggest that there is a gradation between *Lingulina dentaliniformis* Terquem and *Frondicularia dentaliniformis* Terquem, the separation of the species being based only on the shape of the sutures. These two species then grade, by the development of fine ribs, into *Frondicularia nodosaria* Terquem. All these forms were found in the Dogger, and appear to occur in stratigraphic order. If this is true, then it suggests evolution and not simultaneous variation. There is, however, the possibility that, as the striate and ribbed forms occur abundantly in England in the Upper Lias, the rare smooth or faintly striate forms may be extreme variants, and that the more coarsely ribbed forms are the root stock.

Lingulina tenera Bornemann
Plate 1, figures 1-2, 9a-b, 10a-b

Lingulina tenera BORNEMANN, 1854, Liasform. Göttingen, p. 38, pl. 3, fig. 24a-c. – BLAKE, 1876, The Yorkshire Lias, p. 454, pl. 18, figs. 15, 15a. – SCHICK, 1903, Ver. Vaterl. Naturk. Württemberg, Jahreshefte, vol. 59, p. 151, pl. 6, fig. 10. – KLÄHN, 1921, Foraminiferengeschlechter Rhabdogonium, etc., p. 28, pl. 6, figs. 9-23. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 64, pl. 6, fig. 18. – MACFADYEN, 1941, Roy. Soc. London, Philos. Trans., ser. B, vol. 231, no. 576, p. 51, pl. 3, fig. 52a-b. – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 105, pt. 3, p. 365, text-fig. 6a, c, f-g. – USBECK, 1952, Neues Jahrb. Geol. Pal., Abh., vol. 95, no. 3, p. 393, pl. 16, figs. 41-42.

Frondicularia tenera (Bornemann). – TERQUEM, 1858, Premier mémoire sur les foraminifères du Lias, p. 35, pl. 1, fig. 14a-d. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 156, pl. 1A, figs. 11, 19; pl. 2A, fig. 10a-c; pl. 2B, fig. 18a-b; pl. 3, figs. 25-27; pl. 5, fig. 67a-b.

Frondicularia hexagona TERQUEM, 1858, Premier mémoire sur les foraminifères du Lias, p. 34, pl. 1, fig. 13a-b.

Frondicularia pygmaea FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 70, pl. 7, fig. 5a-b. – WICHER, 1938, Preuss. Geol. Landesanst., Abh., new ser., no. 193, pl. 27, figs. 16-17.

Marginulina interlineata TERQUEM, 1858, Premier mémoire sur les foraminifères du Lias, p. 57, pl. 3, fig. 11a-b.

Description: The test consists of a rectilinear series of chambers which slowly increase in size, so that its shape is triangular. It is compressed, but may be biconvex or biconcave. The variation in the shape is largely due to the form of the end chamber and the rate of enlargement of the chambers. Considerable variation occurs in the size of the proloculum, some forms having a small spine at the base.

Usually there are two longitudinal ribs on each side; they surround the proloculum and extend, with equal strength, up the test. Another strong rib extends, keel-like, around the periphery. Its strength varies, and the rib often becomes obsolete on the end chambers. The height of the chambers increases until they are twice as high as broad. The aperture is terminal, central, slit-like, and may be surrounded by a rim or situated at the end of a short neck.

Depository: Geological Survey and Museum, London: no. Mik (M) 458003, 458004; and Barnard collection.

Horizon: bucklandi zone.

Locality: Stowell Park, Northleach, Gloucestershire (Geol. Survey and Museum), and Lyme Regis, Dorsetshire, England (Barnard coll.).

THE LINGULINA TENERA PLEXUS

Introduction

The ribbed Lingulinae of the species-group *L. tenera* Bornemann are, in the author's opinion, best treated as a species plexus of evolving forms. This conclusion is based on a study of the variation in the number and degree of coarseness of the ribs and in the size and shape of the test of specimens from certain stratigraphic horizons. The differences shown in the figures given by previous authors make the task of assigning specimens to different species extremely difficult, especially when, as in most cases, the exact stratigraphic horizon is not given.

The present writer suggests that an overall picture of the plexus is more satisfactory than attempting to split the genus into species or subspecies based on widely variable characters. Certain trends in the evolution of the species plexus are established, even if at times they are somewhat obscured by bursts of variation, due perhaps to changes in environment.

The variation can be established only by a thorough examination of many individuals from adequate sequences of material. This has been done, and the main trends have been noted, as they occur successively in the Lias in cores from the boring at Stowell Park. These forms have also been found in the same sequence in material from the Dorset Coast, the Mendip area, and Yorkshire, confirming the chief trends.

The plexus

Although casts of *Lingulina* have been found in the Rhaetic, the ornament is not preserved, so that the specimens cannot be assigned to a definite species. The earliest Liassic forms occur in the *Ostrea* beds and the *planorbis* zone, and generally are narrow and elongate, agreeing closely with Blake's figure (1876, p. 455, pl. 18, figs. 16, 16a) of his *Lingulina striata* from the *planorbis* zone of Yorkshire. This very long and pointed form, Blake states, is closely allied to *Lingulina tenera:* ". . . its ribs are very fine and irregular, and it puts on several curious shapes . . . and in some the ribs are so unequal as to show the passage to the last-named form" (i.e., *Lingulina tenera*). In the specimens I have seen, no gradation between *Lingulina striata* and *Lingulina tenera* was observed, and there was no tendency for two ribs to become strongly developed. I have recorded similar forms from the *Ostrea* beds and the *planorbis* zone from Stowell Park, southern Yorkshire, Lyme Regis, and Radstock.

In the present paper, *Lingulina striata* Blake is referred to as Form A (see Plate 2 and Plate 3, fig. 1). Form A is more delicate than *Lingulina tenera,* and has about eight chambers. In early forms (that is, from the *planorbis*-zone), the first six chambers show little constriction at the sutures, which are, in fact, scarcely visible; the sides of the test are almost straight and divergent. Only the last and penultimate chambers show well-marked constricted sutures. The ornament consists of six fine striations, which run the whole length of the test (apart from the initial chamber) and occasionally bend inward parallel to the margin of the chambers, where the latter become constricted.

The most important differences between Form A and other forms in the species group are:

1) The initial chamber is apiculate and the small spine is not connected with the ribs or striations. (This is not shown in Blake's figure, but specimens are often abraded.)

2) On the initial end of the test, the two outer ribs of the six begin at the base, the remaining four being added in pairs inside the first two.

3) Perhaps the most important difference is that no ribs occur around the edge of the test to form a keel.

4) All ribs or striations are of equal strength.

As Form A evolves to Form A′ (pl. 3, fig. 2), the test becomes more elongate and the constrictions between the chambers become more pronounced. The ribs vary slightly in strength, but none differs markedly from the others. As with other species of *Lingulina*, elongation apparently heralds extinction, for Form A dies out in the *angulatum* zone. Elongation and constriction lead to a weaker test, and extinction may be a result of this factor. These changes in Form A have been observed in specimens from Radstock, Stowell Park, Yorkshire, and Lyme Regis, and are therefore well established.

Form B, i.e., *Lingulina tenera*, appears to be the main stock of the plexus, from which most of the other variants arose. The form is long-ranging, and at certain horizons specimens are extremely abundant. Although a description of *Lingulina tenera* sensu stricto has already been given, there is considerable variation. Variants are shown in the diagram (Plate 2).

The typical Form B is usually a robust form with six well developed strong ribs, including a well defined keel. Two ribs develop on either side of the test, surrounding the globular megalosphere, and then continue up the test with fairly constant emphasis. In forms in which the sutures become constricted in the last chambers, however, the ribs die out. In the microspheric generation, the ribs project beyond the microsphere and join to give a pseudo-apiculate end. The two ribs which form the keel develop early, either on the first or second chamber after the proloculum.

There are considerable differences in shape and degree of ornamentation between mature and immature specimens, and in the past this has often led to misidentification. At some horizons, immature specimens occur in profusion and predominate. In the microspheric form, the edges of the test are usually straight and divergent, whereas in megalospheric specimens the edges are curved, and the ribs are often parallel to the margins of the test. The chief feature separating Form B and its immature specimens from other variants is that the test between the main ribs is smooth, whereas in other forms subsidiary costation or striations appear.

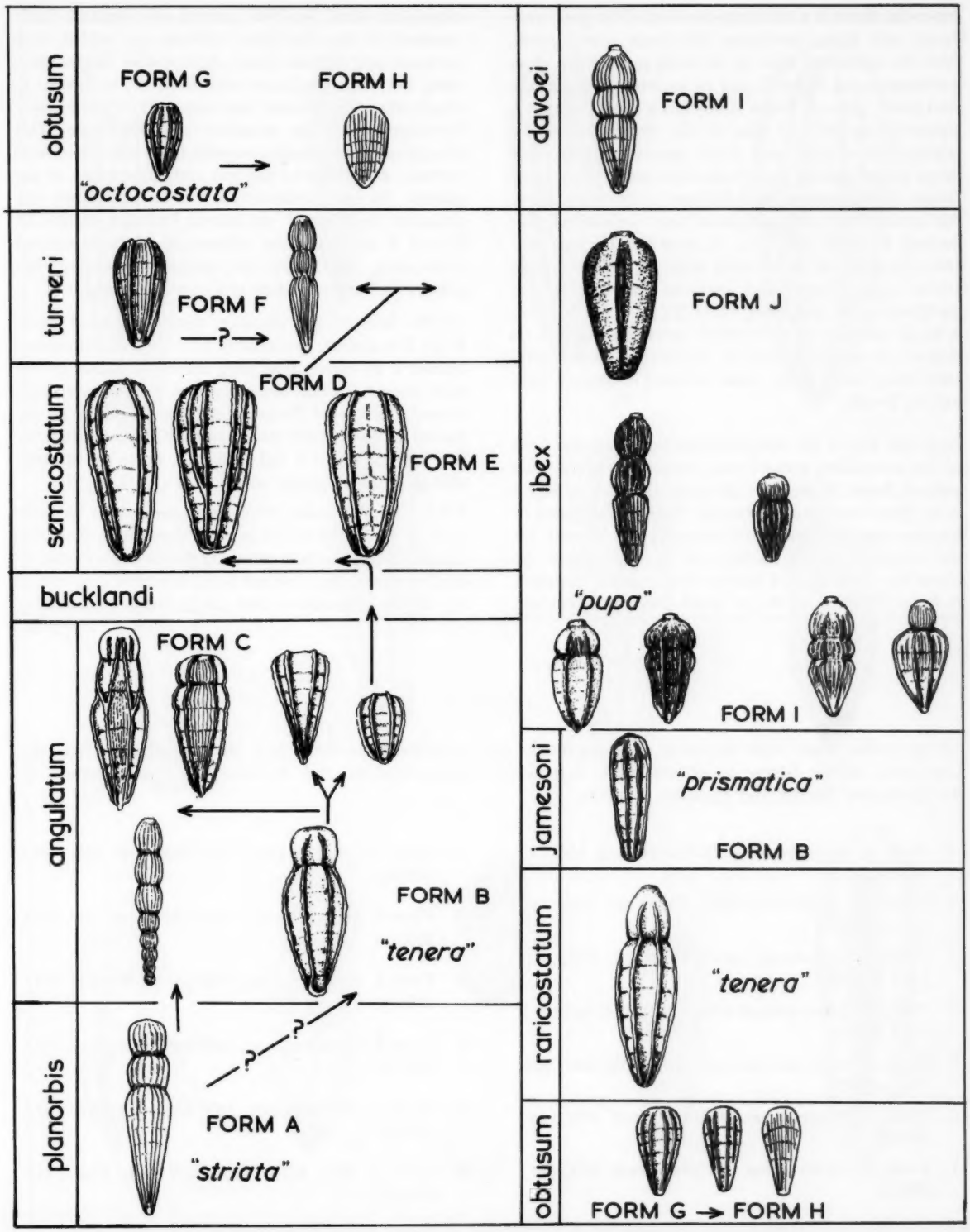
Forms A and B characterise the lower part of the *angulatum* zone, but Form A soon becomes extinct, and Form B then continues with Form C, a variant derived from Form B. Form C (pl. 3, fig. 3) differs from Form B in having about six fine striations occupying the centre of each side of the test and interposed between the two main costae. The two main ribs extend around the proloculum, giving the impression that the initial end of the test is apiculate. The fine striae vary considerably in their degree of development but are usually persistent, except on the end chamber and on the later chambers of forms with highly constricted sutures. That part of the test between the main costae and the keel is smooth in all the numerous specimens from the early zones that I have studied.

Some extreme variants of Form C, usually showing a change in ornament, are correlated with a high degree of constriction at the sutures, particularly of the later chambers. The earlier part of the test has a curved periphery as in the normal Form C, a keel, two central ribs, and fine striations between the latter. The last two or three chambers become constricted. Before the constricted chambers are added, the two main costae split, and one additional rib is developed from each of these. But the two main costae persist over several of the constricted chambers before decreasing in strength and finally dying out. The new ribs diverge from their parent ribs at an angle of about thirty degrees and eventually either coalesce with or replace the peripheral keel, particularly where this has grown weak or disappeared. Two short ribs also occur between the peripheral and central pair, all these ribs being equally strong. Over the end chamber the peripheral keel often becomes obsolete. This variation from Form B through Form C to the extreme forms of Form C occurs in the *angulatum* zone of Stowell Park, Lyme Regis, Radstock, and Yorkshire.

Throughout the remainder of the *angulatum* and *bucklandi* zones, and through most of the *semicostatum* zone, both Form B and Form C, together with its extreme variants, are found. At certain horizons,

PLATE 2

Diagrammatic representation of the various forms within the *Lingulina tenera* plexus that occur in the Lias.


obtusum
FORM G
FORM H
"octocostata"
turneri
FORM F
?
semicostatum
FORM D
FORM E
bucklandi
angulatum
FORM C
FORM B
"tenera"
planorbis
?
?
FORM A
"striata"
davoei
FORM I
ibex
FORM J
"pupa"
FORM I
jamesoni
"prismatica"
FORM B
raricostatum
"tenera"
obtusum
FORM G → FORM H

however, there is a tendency for Form B to grow very large, and these specimens, like their parent stock, have no subsidiary ribs. In the early part of the *semicostatum* zone, Form C and its varieties become rare and finally die out. Form B reaches a climax of development, especially in size, in the upper part of the *semicostatum* zone, and large specimens with very large megalospheric prolocula occur here. These large forms show ornamentation of three main types: First, the normal kind with peripheral and two central ribs; second, Form D (pl. 3, fig. 4), in which the two central ribs give rise at an early stage to two additional coarse costae interposed between the central and peripheral ribs; and third, Form E (pl. 3, fig. 5), with a single median rib developed, varying greatly in its degree of emphasis and its regularity. These variations were found at the same horizons at Stowell Park and in Dorset.

Near the top of the *semicostatum* zone and the base of the succeeding *turneri* zone, these three main variants of Form B continue in great abundance. However, there are two main trends: First, for all forms to become narrower and more elongate, and second, for the variant with the median rib to predominate. At about the same time, a further development is shown in Form F (pl. 3, fig. 6), of which there are abundant examples. Here the two central ribs remain fairly constant in size, but fine striations are added both between and outside them. Arising also at the same time, but with gradation from Form F, is a form in which the two central ribs are only slightly more developed than the striations on either side. This change of ornamentation appears to be correlated with extreme elongation of the test and constriction of the sutures. In such constriction I have not found any gradation to Form F. At several horizons, Forms D, E and F seem to vary alternately in their relative abundance, but finally the elongate forms and the constricted striate variant of Form F disappear.

At the base of the *obtusum* zone at Stowell Park, Form B is absent; presumably an adverse environment caused it to vacate that area, although higher in the same zone it is again found there. A temporary change caused the keeled forms to disappear and to be replaced by forms with strong costae. These range from four ribs, in Form G (pl. 3, fig. 7), up to ten straight ribs of equal emphasis, in Form H (pl. 3, fig. 8).

Forms G and H occur in this zone for a short distance only, and a return to the more normal Form B occurs higher in the *obtusum* zone. Together with Forms G and H, a new, rare, ribbed form is found. It is unlike any of the *Lingulina tenera* group but is very similar

PLATE 3

All specimens drawn with the aid of a camera lucida, and magnified approximately × 99. All specimens from the Geological Survey boring at Stowell Park, Northleach, Gloucestershire, and deposited in the collections of the Geological Survey and Museum, London.

1 Form A: *planorbis* zone, 2010-2020 feet; Mik (M) 458006.

2 Form A′: *angulatum* zone, 1950-1960 feet; Mik (M) 458007.

3 Form C: *angulatum* zone, 1920-1930 feet; Mik (M) 458008.

4 Form D: *semicostatum* zone, 1640-1650 feet; Mik (M) 458009.

5 Form E: *semicostatum* zone, 1640-1650 feet; Mik (M) 458010.

6 Form F: *turneri* zone, 1620-1630 feet; Mik (M) 458011.

7 Form G: *turneri* zone, 1620-1630 feet; Mik (M) 458012.

8 Form H: *turneri* zone, 1620-1630 feet; Mik (M) 458013.

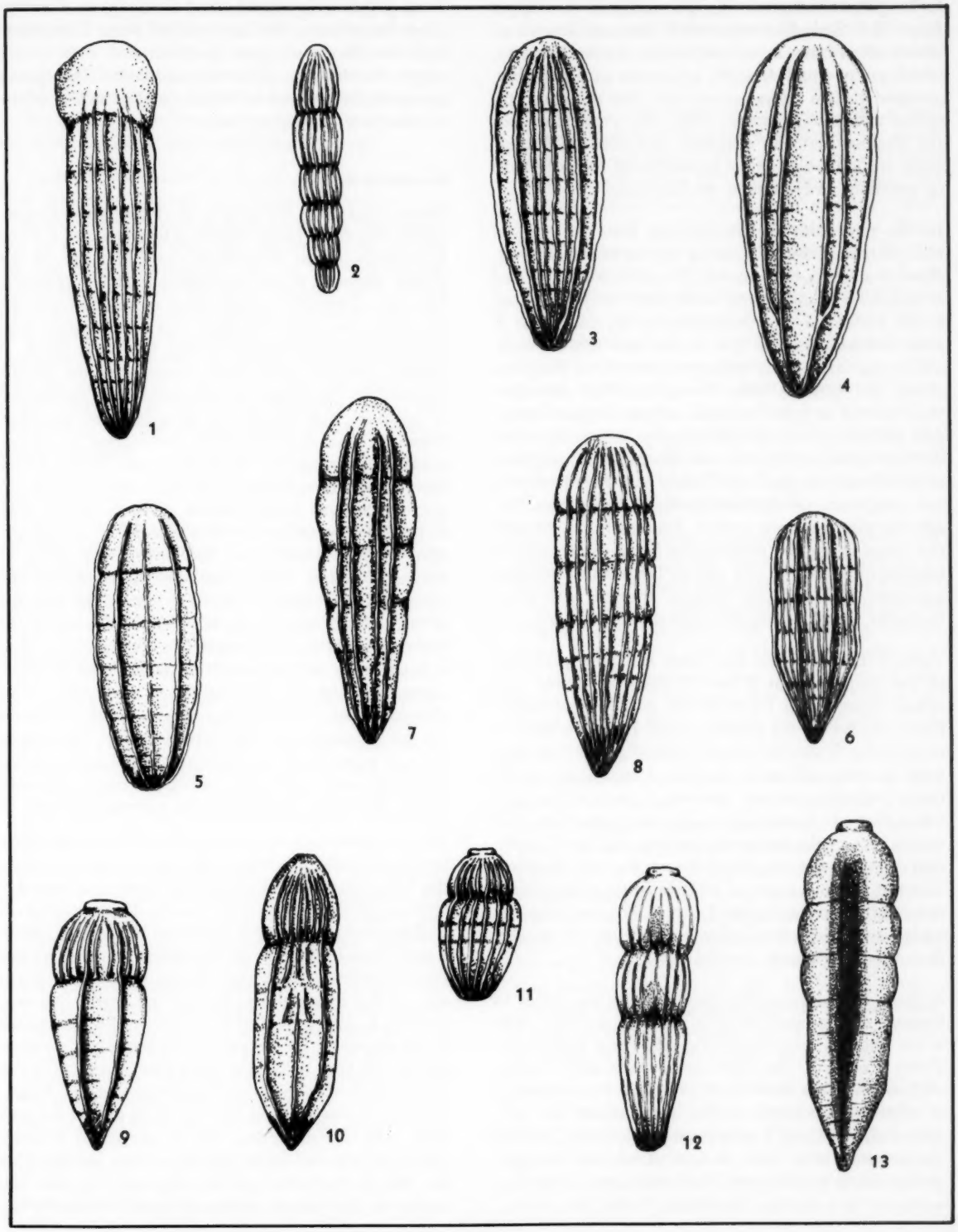
9 Form I: *obtusum* zone, 1450-1460 feet; Mik (M) 458014.

10 Form I: *obtusum* zone, 1450-1460 feet; Mik (M) 458015.

11 Form I: *obtusum* zone, 1450-1460 feet; Mik (M) 458016.

12 Form I: *obtusum* zone, 1450-1460 feet; Mik (M) 458017.

13 Form J: *ibex* zone, 1000-1010 feet; Mik (M) 458018.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to *Lingulina nodosaria* (Terquem), from the Upper Lias. This form has constricted flattened chambers, which often have a pseudochevron shape. The ribs, which are of equal strength, appear on each chamber, grouped in two lateral areas. It is this grouping, together with the curvature of the ribs, which produces the illusion that the chambers are chevron-shaped. Each rib is curved either parallel with the periphery or convexly away from a median sinus.

In the remainder of the *obtusum* zone and in the basal *bispinigerum* subzone of the *raricostatum* zone, there is a return of Forms B, G and H. Forms G and H gradually become rarer until finally they disappear in the middle of the *raricostatum* zone, and Form B alone remains. In the rest of the *raricostatum* zone and in the succeeding *jamesoni* zone, Form B occurs alone, and there is little divergence from the main stock except at some horizons where elongate examples are found with the ribs obsolete, especially when the later sutures of the test are constricted. Elongation is not always coupled with highly constricted sutures, but progresses slowly through these zones until finally the race becomes extinct. Another trend through this range is for the central area between the ribs to become excavated, giving rise to Terquem's *Lingulina excavata*. The ribs also become stronger and often knife-like, emphasizing the central concave area.

Toward the top of the *ibex* zone, elongate specimens of the normal Form B are replaced by ribbed and striate types, Form I (pl. 3, figs. 9-12). Most of the forms present do not possess a keel, but have the two central ribs, in varying stages of development, together with a series of small, ill-defined striations, which occur irregularly or only on certain parts of the test. Often they are found only on the later chambers, the earlier part of the test being smooth, and occasionally only between the two main ribs on the end chamber. The test is more rounded and the sutures more constricted than in the normal Form B. The end chamber varies in shape, often being much larger or smaller than the penultimate chamber.

In these Lingulinae of the *ibex* zone, the test tends to become narrow and elongate, and the usually eight to ten ribs and striae tend to become equal in strength. There is no keel. This form, however, is only a minor offshoot from the main stock, which is very abundant in subsequent horizons. A new trend causes the subsidiary ribs of Form I to become obsolete first, leaving the two main ribs. These, in turn, slowly lose strength, giving rise to smooth forms with the centre of the test occupied by a shallow depression, Form J.

Form J (pl. 3, fig. 13) is short-lived, for in the overlying *davoei* zone, the many-ribbed Form I described from the *ibex* zone again predominates, with a wide range of coarseness of the ribs and striae. The species group finally appears to become extinct in the sandy-silty beds of the Upper Lias.

Discussion of the plexus

Before discussing the plexus, it is necessary to summarize the main points briefly. The main stock, Form B, extends almost throughout the full range of the plexus, although it may be slightly modified at certain horizons. Generally, modification is found where the specimens are most abundant, and may coincide with a favourable environment. From the main stock, at certain horizons, there arise forms that are usually modified in the degree of ornamentation, occurrence of striations, and strength of the ribs. These modifications are often well established, occurring in a large number of specimens, but the form usually has a very short range. Elongation of the test often heralds extinction. Several forms become elongate, which may or may not be coupled with a change in ornamentation. Similar trends from the main stock occur at various localities and at different horizons. All the main trends in ornamentation are toward the addition of more ribs or, more especially, striae. The trends are not connected in time, each being distinct, so that, although their ultimate result is the insertion of striae, convergence to true similarity does not quite occur. Homeomorphy is thus not complete, and the forms can be differentiated only with difficulty. The trends are not represented by isolated examples but by an abundant fauna, with many specimens occupying links in the chain from Form B to the extreme variants.

The disappearance of one form for a limited time may be due to a slight change in the environment, causing the form to migrate. Usually, however, if a form disappears, it does not return again. This problem of shifting environments was discussed by Joysey (1952). I have found difficulty in attempting to correlate the type of sediment with the relative abundance or the size of the foraminifera. In fact, no correlation was perceived, although different genera often behaved in the same way, for instance, all increasing or decreasing in size (but not at the same rate). In spite of the many trends displayed by this plastic stock of *Lingulina tenera*, few of them survived long except the root form. The various trends toward increased striation all developed end forms that were very similar. This has led to confusion in the literature, so that the ranges of the various species proposed cannot be ac-

cepted; examples of this will be given later. The main trends were repeated time and time again, with only minor differences. All that can be said, therefore, is that the root stock went through the full time-range of the plexus almost unchanged, and that variants neither persisted for long nor apparently gave rise to any new, persistent, well established species.

No evidence was found to support recapitulation. In most specimens, the ribs are constant throughout the growth of the test, except on the variable end chamber. In a few forms from the *davoei* zone of France, the test was ornamented only on the last-formed chambers; this would indicate a smooth or bi-ribbed ancestor. But specimens were also found with the early stages of the test having full ornament, later chambers being smooth. All these variations point to a highly plastic stock, and it is felt that, while the above account may not be the complete story, the treatment of the group as a plexus presents a rather accurate picture.

Range of the species

In 1950 (Barnard, 1950*a* p. 367), the writer pointed out some of the difficulties in recognising the species, particularly the finely striate forms, which had been assigned by various authors to *Lingulina pupa* Terquem. In most cases, however, I had only the figures in the literature to compare with my specimens, and these figures are not always accurate.

1) *Frondicularia hexagona* Terquem (1858, pl. 1, fig. 13a-c), the specimens of which I have seen, is the present Form B, *Lingulina tenera* Bornemann, sensu stricto. *Frondicularia tenera* (Bornemann) of Terquem (1858, pl. 1, fig. 14a-d) is badly figured and bears little resemblance to the specimens, which are Form B.

   Marginulina pupa Terquem (1866*a*, pl. 17, fig. 7a-f) is a cause of difficulty. The range given by Terquem is from the Lower Lias, presumably the *bucklandi* zone, to the *davoei* zone, from Vallières-lès-Metz, Vic (Indre), and Venarey (Semur). It may be that Terquem confused Form F and Form I, the form from the higher zones of the Lower Lias. Unfortunately, the author managed to find only one of Terquem's slides labelled *Marginulina pupa*, from the "Lias infr., Ass. à gryphées arquées," Vallière-lès-Metz. This specimen has ten ribs of nearly equal strength, and is probably Form H.

2) *Lingulina tenera* Bornemann of Franke (1936, pl. 6, fig. 18), from the Middle Lias, is equivalent to Form B of *Lingulina pupa* (Terquem), also figured by Franke (1936, pl. 6, figs. 16a-b, 17). The three figures are of forms from the higher zones of the Lower and Middle Lias, and are probably Form I.

3) Bartenstein and Brand (1937) dealt with a continuous section of the Lias, and figured the specimens in zonal groups, so that it is easier to compare the succession of forms. These authors described several new subspecies, most of which were assigned to the genus *Frondicularia*. Their *Frondicularia tenera tenera* (Bornemann) (Bartenstein and Brand, 1937, pl. 1A, figs. 11, 19) is Form B from the *angulatum* zone. Their Plate 2A, figure 10b and c, are also normal Form B, but their figure 10a is clearly comparable with Form E, a form like *Lingulina tenera* sensu stricto but having an additional central rib. This form appears to occur earlier in Germany than in Britain. *Frondicularia tenera tenera* (Bornemann) of Bartenstein and Brand (1937, pl. 2B, fig. 18a), from the *bucklandi* zone, is equivalent to Form E as above, but their figure 18b is the normal Form B.

   Frondicularia tenera prismatica Bartenstein and Brand (1937, pl. 3, fig. 34a-c), from the Lias β, appears to be a form representing a similar episode occurring almost contemporaneously with that in Britain, a period when the test of the normal Form B tended to narrow and become elongate. As this trend, probably due to environment, appears at several horizons, the present writer believes that this form is not of sufficient importance to warrant the use of a separate name.

   Frondicularia tenera tenera (Bornemann) of Bartenstein and Brand (1937, pl. 3, figs. 25-26), from the *planicosta* subzone, is our Form B. *Frondicularia tenera octocostata* Bartenstein and Brand (1937, pl. 3, fig. 27) has two additional ribs on either side of the test, but it is not clear whether these extend the full length of the test, as in Form H, or bifurcate from the main central costae, as in Form D. *Lingulina pupa* (Terquem) of Bartenstein and Brand (1937, pl. 4, figs. 52a-b and 53a-b), from the Lias γ, are Form I and its varieties. Their *Lingulina pupa* (Terquem) (pl. 5, figs. 32a-b, 33), from the Middle Lias, appear to be Form I.

4) *Lingulina tenera tenera* (Bornemann) of Usbeck (1952, pl. 16, fig. 41), from the Lias α, is Form B. His *Lingulina tenera pupa* (Terquem) (pl. 16, fig. 42) may be Form A or a specimen approaching Form B, for, although it shows fine striations, two main ribs are prominent.

5) *Lingulina tenera* Bornemann of Macfadyen (1941, pl. 3, fig. 2) is Form B, whilst his *Lingulina tenera* var. *pupa* (Terquem) (1941, pl. 3, fig. 3) is clearly Form I.

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BIBLIOGRAPHY

BARNARD, T.
1950*a* – *Foraminifera from the Lower Lias of the Dorset Coast.* Geol. Soc. London, Quart. Jour., vol. 105, pt. 3, no. 419, pp. 347-391, text-figs. 1-11, 1 chart.

1950*b* – *Foraminifera from the Upper Lias of Byfield, Northamptonshire.* Ibid., vol. 106, pt. 1, no. 421, pp. 1-36, pls. 1-3, text-figs. 1-17.

BARTENSTEIN, H., AND BRAND, E.
1937 – *Mikro-paläontologische Untersuchungen zur Stratigraphie des nordwest-deutschen Lias und Doggers.* Senckenb. Naturf. Ges., Abh., no. 439, pp. 1-224, pls. 1-20, text-figs. 1-20, 5 tables.

BERTHELIN, G.
1879 – *Foraminifères du Lias moyen de la Vendée.* Rev. Mag. Zool., ser. 3, vol. 7, pp. 24-41, pl. 1.

BLAKE, J. F.
1876 – *Class Rhizopoda.* In: TATE, R., AND BLAKE, J. F., *The Yorkshire Lias.* London: J. van Voorst, pp. 449-473, pls. 17-19.

BORNEMANN, J. G.
1854 – *Ueber die Liasformation in der Umgegend von Göttingen, und ihre organischen Einschlüsse.* Berlin: A. W. Schade, pp. 1-45, pls. 1-4.

BRADY, H. B.
1867 – *Foraminifera.* In: MOORE, C., *On the Middle and Upper Lias of the south-west of England.* Somersetshire Archaeol. Nat. Hist. Soc., Proc., vol. 13 (1865-1866), pt. 2, pp. 220-236, pls. 1-3.

CRICK, W. D., AND SHERBORN, C. D.
1891 – *On some Liassic foraminifera from Northamptonshire.* Northamptonshire Nat. Hist. Soc., Jour., vol. 6, pp. 208-214, 1 pl.

1892 – *On some Liassic foraminifera from Northamptonshire; Part 2 – The Leda-ovum beds of the upper Lias.* Ibid., vol. 7, pp. 67-73, 1 pl.

CUSHMAN, J. A.
1940 – *Foraminifera: Their classification and economic use.* Ed. 3. Cambridge, Mass.: Harvard University Press, pp. 1-535, pls. 1-31; Key, pls. 1-48, 8 text-figs.

DEECKE, W.
1886 – *Les foraminifères de l'Oxfordien des environs de Montbéliard (Doubs).* In: KILIAN, W., *Notes géologiques sur la Jura du Doubs; Quatrième partie.* Soc. Emul. Montbéliard, Mém., vol. 16 (ser. 3, vol. 6), pp. 289-335, pls. 1-2.

FRANKE, A.
1936 – *Die Foraminiferen des deutschen Lias.* Preuss. Geol. Landesanst., Abh., new ser., no. 169, pp. 1-138, pls. 1-12.

GREEN, G. W., AND MELVILLE, R. V.
1956 – *The stratigraphy of the Stowell Park borehole (1949-1951).* Great Britain, Geol. Survey, Bull., no. 11, pp. 1-66, pl. 1.

ISSLER, A.
1908 – *Beiträge zur Stratigraphie und Mikrofauna des Lias in Schwaben.* Palaeontographica, vol. 55, fasc. 1, pp. 1-103, pls. 1-7.

JONES, T. R., AND PARKER, W. K.
1860 – *On some fossil foraminifera from Chellaston near Derby.* Geol. Soc. London, Quart. Jour., vol. 16, pp. 452-458, pls. 19-20.

JOYSEY, K. A.
1952 – *Fossil lineages and environmental change.* Geol. Mag., vol. 89, pt. 5, p. 357.

KLÄHN, H.
1921 – *Die Foraminiferengeschlechter Rhabdogonium, Cristellaria und Frondicularia der elsassischen und badischen Juraschichten.* Freiburg im Breisgau: The author, 1921, pp. 1-75, pls. 1-6.

MACFADYEN, W. A.
1941 – *Foraminifera from the Green Ammonite beds, Lower Lias, of Dorset.* Roy. Soc. London, Philos. Trans., ser. B, vol. 231, no. 576, pp. 1-73, pls. 1-4, text-figs. 1-6.

MELVILLE, R. V.
1956 – *Stratigraphical palaeontology, ammonites excluded, of the Stowell Park borehole.* Great Britain, Geol. Survey, Bull., no. 11, pp. 67-139, pls. 2-8.

SPATH, L. F.
1956 – *The Liassic ammonites of the Stowell Park borehole.* Ibid., pp. 146-164, pls. 9-10.

TERQUEM, O.
1858 – *Mémoire sur les foraminifères du Lias du département de la Moselle; Partie I.* Acad. Imp. Metz, Mém., vol. 39 (ser. 2, vol. 6) (1857-1858), pp. 563-654, pls. 1-4.

1862 – *Recherches sur les foraminifères du Lias; Second Mémoire.* Ibid., vol. 42 (ser. 2, vol. 9) (1860-1861), pp. 415-466, pls. 5-6.

1864*a* *Troisième mémoire sur les foraminifères du Lias des départements de la Moselle, de la Côte-d'Or, du Rhône, de la Vienne et du Calvados.* Ibid., vol. 44 (ser. 2, vol. 11) (1862-1863), pp. 361-438, pls. 7-10.

1864*b* *Quatrième mémoire sur les foraminifères du Lias, comprenant les Polymorphines des départements de la Moselle, de la Côte-d'Or et de l'Indre.* Metz: Lorette, pp. 233-308, pls. 11-14.

1866*a* *Cinquième mémoire sur les foraminifères du Lias des départements de la Moselle, de la Côte-d'Or et de l'Indre, avec un aperçu stratigraphique et pétrologique des environs de Nohant.* Metz: Lorette, pp. 313-454, pls. 15-18.

1866*b* *Sixième mémoire sur les foraminifères du Lias des départements de l'Indre et de la Moselle.* Metz: Lorette, pp. 459-532, pls. 19-22.

1870 – *Troisième mémoire sur les foraminifères du Système Oolithique, comprenant les genres Frondicularia, Flabellina, Nodosaria, Dentalina, etc. de la zone à Ammonites parkinsoni de Fontoy (Moselle).* Acad. Imp. Metz, Mém., vol. 51 (ser. 2, vol. 18) (1869-1870), pp. 299-380, pls. 22-29.

TERQUEM, O., AND BERTHELIN, G.
1875 – *Étude microscopique des marnes du Lias moyen d'Essey-lès-Nancy, zone inférieure de l'assise à Ammonites margaritatus.* Soc. Géol. France, Mém., ser. 2, vol. 10, no. 3, pp. 1-126, pls. 1-10 (11-20).

USBECK, I.
1952 – *Zur Kenntnis von Mikrofauna und Stratigraphie im unteren Lias alpha Schwabens.* Neues Jahrb. Geol. Pal., Abh., vol. 95, no. 3, pp. 371-476.

ABSTRACT: *For those in search of markers, a range chart, together with descriptions and figures, of five rare Jurassic index foraminifera is presented here. These forms have been described by the author in various papers within the past five or six years, and it was believed desirable to assemble and present this information here because of its possible economic applications.*

Some rare Jurassic index foraminifera

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INTRODUCTION

During 1950, a short paper was published by the present author on Jurassic microfossils of the Tyrolean Alps. Two new genera and one species that are markers were described. Two other genera known only from the Jurassic have also been described by the author in the interval since 1950. These forms cannot yet be found in any textbook or catalogue of foraminifera, and this note is therefore intended as a supplement to the textbooks and catalogues now in use, as an aid to micropaleontological laboratories. It is hoped that this information will be of assistance when drilling is proceeding in Jurassic limestone sections where the age can be determined only by the use of thin sections.

STRATIGRAPHY

A brief summary of the Jurassic stratigraphy of the area in question is given below:

The Jurassic beds of the Sonnwend Mountains in the Tyrol are divided into the Middle Jurassic lower Dogger and middle and upper Dogger, and the Upper Jurassic Malm. The lower Dogger consists of a rather shallow-water radiolarian deposit several meters thick, in which none of the markers discussed here is found. The middle and upper Dogger consists of the so-called "hornstone breccia." This is a limestone with a large amount of siliceous sediment, containing allochthonus reworked breccia fragments. This coarse clastic material is a sediment derived from a shore with open reef-shoals. The temperature is believed to have been rather warm, because corals and algae also lived in the very shallow water.

The Malm beds consist in part of reef limestone, which is mixed with fine reworked coastal detritus. They show intersecting portions of the fore-reef transition zone, which was also a very shallow and warm-water area. In part, these beds show a rather high dolomite content. Silicification of the sediment began during the early stages of its consolidation. In contrast to the "hornstone breccia," the breccia portions of the Malm limestone beds are composed of much finer particles.

SYSTEMATIC DESCRIPTIONS

For more complete descriptions of the forms discussed below, the reader is referred to the publications listed in the bibliography.

Family OPHTHALMIDIIDAE

Genus **Aulotortus** Weynschenk, 1956

Aulotortus WEYNSCHENK, 1956, Cushman Found. Foram. Res., Contr., vol. 7, pt. 1, p. 26.

Test calcareous, imperforate. The wall of the spiral tube shows irregular sinuses and thickenings. The whorls are twisted, the oldest whorls closely appressed, the younger whorls uncoiling. A vertical section of the tube is crescent-shaped. The tube is not subdivided into chambers. The initial portion is filled on both sides with calcium carbonate, so that the form as a whole is lenticular. Proloculus globular.

Genotype: Aulotortus sinuosus Weynschenk, 1956 (pl. 1, figs. 1-3; text-fig. 1).

Family LITUOLIDAE

Genus **Labyrinthina** Weynschenk, 1951

Labyrinthina WEYNSCHENK, 1951, Jour. Pal., vol. 25, no. 6, p. 793; 1954, The Micropaleontologist, vol. 8, no. 3, p. 47.

Wall arenaceous. Chambers labyrinthic, expanding in adult stages; may be encrusting, or free and uniserial. Chambers

TABLE 1

RANGE CHART

	Middle Jurassic (middle and upper Dogger)	Upper Jurassic (Malm)
Aulotortus sinuosus Weynschenk	———	——— ? ———
Labyrinthina mirabilis Weynschenk		———
Conicospirillina cf. *basiliensis* Mohler	———	———
Protopeneroplis striata Weynschenk	———	———
Ventrolamina cribrans Weynschenk	——— ? ———	———

PLATE 1

1 *Aulotortus sinuosus* Weynschenk
Vertical section, × 78. Torsion of the whorls and irregular wall structure of the crescent-shaped tube section on the left are clearly shown.

2 *Aulotortus sinuosus* Weynschenk
Horizontal section, × 35. No subdivision of the tube can be seen. Irregular sinuses and thickenings of the tube wall are indicated by the white arrow.

3 *Aulotortus sinuosus* Weynschenk
Vertical section, × 30. See also text-figure 1.

4 *Labyrinthina mirabilis* Weynschenk
Specimen encrusting a detrital fragment, × 30.

5, 7 *Labyrinthina mirabilis* Weynschenk
Transverse sections showing irregular labyrinthic chambers: 5, × 47; 7, × 26.

6 *Labyrinthina mirabilis* Weynschenk
Attached form, section, × 18, showing the irregular spiral of the oldest chambers (*A*) and the later uncoiled encrusting chambers (*B*).

8 *Labyrinthina mirabilis* Weynschenk
Section, × 25, of a free uncoiled specimen in which the youngest chambers have become very broad and uniserial.

9–10 *Conicospirillina* cf. *basiliensis* Mohler
Vertical sections: 9, × 35; 10, × 60. The typical umbilical bands shown in the photographs are caused by the overlapping of secondary calcareous material of the youngest coils upon the older parts of the tubular chamber in the umbilicus.

11 *Protopeneroplis striata* Weynschenk
Horizontal section, × 110, of a macrospecimen, showing bent overlapping bands of calcareous material between the whorls, following the trend of the spiral. These typical bands are also found on the umbilical side of *Conicospirillina* cf. *basiliensis* Mohler (figs. 9-10), but in contrast to those of *Protopeneroplis striata*, the bands in *Conicospirillina* cf. *basiliensis* are irregularly arranged on the umbilical side of the specimen. The globular proloculus, and the interrupted chamber walls indicating an areal aperture, are also visible.

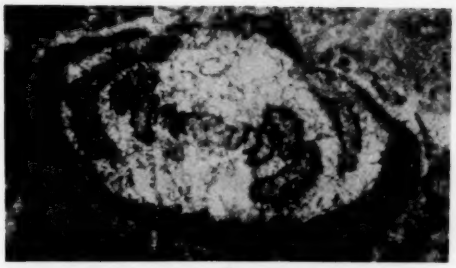
12 *Protopeneroplis striata* Weynschenk
Vertical section, × 130, of a macrospecimen. The typical accentuated dark bands of calcareous perforate material between the whorls are visible. The specimen shows a secondary oolitic wall on the outer edge.

13 *Protopeneroplis striata* Weynschenk
Horizontal section, × 83, of a microspecimen. Uncoiling throughout.

14–15 *Ventrolamina cribrans* Weynschenk
Vertical sections, × 73. Fig. 15 shows the apertures opening into the ventral sieve-plate. The sieve-plate terminates at its base in a wedge composed of calcareous lamellae.

16 *Ventrolamina cribrans* Weynschenk
Horizontal dorsal section (B-B in text-fig. 3), × 65, showing the chambers enclosed by a secondary oolitic band on the outside of the specimen.

17 *Ventrolamina cribrans* Weynschenk
Horizontal section on the ventral side of the chambers (A-A in text-fig. 3), × 70. The section passes through the proloculus and intersects a small part of the second chamber, the sieve-plate, and the last chamber. The spongy sieve-plate between the chambers, and its structure, are clearly shown. The biconvex form of the specimen is also revealed.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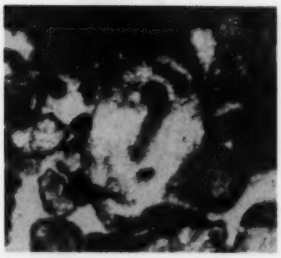
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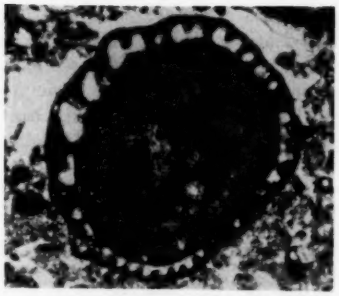
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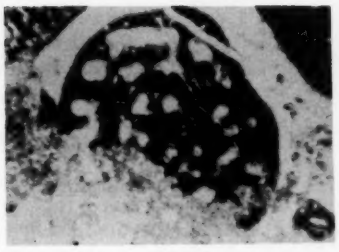
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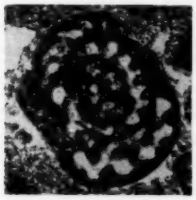
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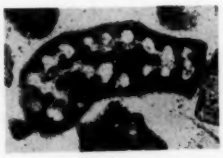
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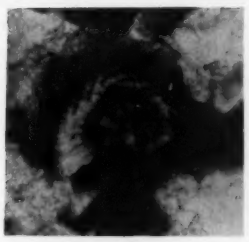
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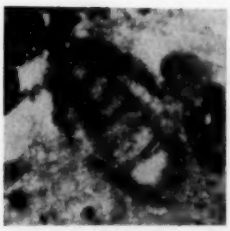
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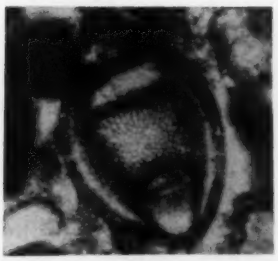
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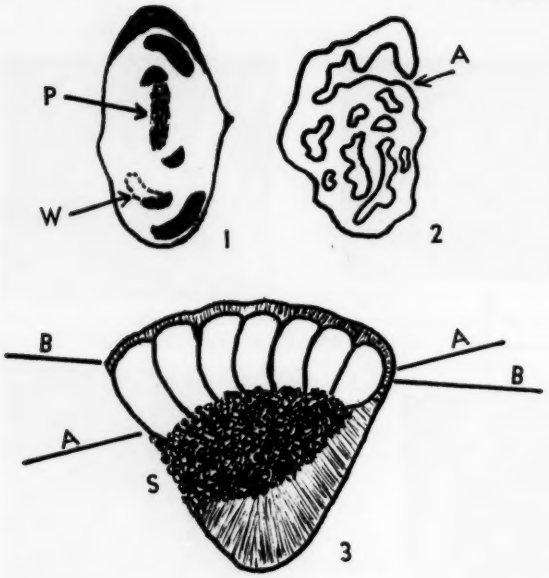

TEXT-FIGURES 1-3

1, *Aulotortus sinuosus* Weynschenk, vertical section (drawn from pl. 1, fig. 3). Tortion of the tube is accentuated in the drawing. *P* indicates part of the proloculus with the first close coils. The adult stages of the specimen show the twisted portions (in black) of the tube, as in pl. 1, fig. 1. *W* indicates a schematic section through the tube, not clearly seen in the photograph (pl. 1, fig. 3). 2, *Labyrinthina mirabilis* Weynschenk, section of specimen showing aperture (*A*) at base of last chamber. 3, *Ventrolamina cribrans* Weynschenk, vertical section showing the position of the horizontal sections A-A and B-B described in pl. 3, figs. 16-17. *S* indicates the spongy sieve-plate with its sieve canals opening toward the front of the specimen as well as toward the convex sides.

irregularly planospiral in arrangement. Proloculus globular. Aperture in uncoiled forms probably terminal, in planospiral forms at base of last chamber.

Genotype: Labyrinthina mirabilis Weynschenk, 1951 (pl. 1, figs. 4-8; text-fig. 2).

Family ROTALIIDAE

Genus CONICOSPIRILLINA Cushman, 1927

Conicospirillina cf. **basiliensis** Mohler
Plate 1, figures 9-10

Conicospirillina cf. *basiliensis* Mohler.—WEYNSCHENK, 1950, Schlern-Schriften, Innsbruck, no. 83, p. 16, pl. 2, fig. 18; pl. 3, fig. 19.

This foraminiferan differs from the description of *Conicospirillina* Cushman in that the spiral chamber is coiled only slightly conically, so that the specimen is rather flat. This often causes very broad, accentuated black bands to appear on the umbilical side of the specimen in vertical sections.

Family PENEROPLIDAE

Genus **Protopeneroplis** Weynschenk, 1950

Protopeneroplis WEYNSCHENK, 1950, Schlern-Schriften, Innsbruck, no. 83, p. 13.

Shell calcareous, perforate. Wall agglutinated. Test planispiral, involute, bilaterally symmetrical. Chambers always loosely coiled, with calcareous perforate shell material between the whorls. The calcareous shell material between the whorls shows typically as dark bands in thin sections, caused by the overlapping of the calcareous perforate material during growth. The bands are arranged like bent ribs following the trend of the spiral. Proloculus globular. Aperture areal.

Genotype: Protopeneroplis striata Weynschenk, 1950 (pl. 1, figs. 11-13).

Family VENTROLAMINIDAE

Genus **Ventrolamina** Weynschenk, 1950

Ventrolamina WEYNSCHENK, 1950, Schlern-Schriften, Innsbruck, no. 83, p. 17.

Shell calcareous, perforate. Wall agglutinated. Test bilaterally symmetrical, biconvex. Proloculus rounded ovate, but somewhat flattened against the second chamber. Chambers uniserial, arranged in a slight curve. There is no communication between the chambers; the apertures of the chambers are situated on the ventral side of the specimen, and are connected with a rather thick sieve-plate that has a spongy structure and is biconvex in shape. Farther down, the sieve-plate develops radial calcareous lamellae that terminate in a flat wedge.

Genotype: Ventrolamina cribrans Weynschenk, 1950 (pl. 1, figs. 14-17; text-fig. 3).

BIBLIOGRAPHY

WEYNSCHENK, R.

1950 – *Die Jura-Mikrofauna und flora des Sonnwendgebirges (Tirol).* Schlern-Schriften, Innsbruck, no. 83, pp. 1-32, pls. 1-3, tfs. 1-5, table 1.

1951 – *Two new foraminifera from the Dogger and Upper Triassic of the Sonnwend Mountains of Tyrol.* Jour. Pal., vol. 25, no. 6, pp. 793-795, pl. 112, tfs. 1-3, table 1.

1954 – *A note on the Jurassic markers Pseudocyclammina lituus Yabe and Hanzawa and Labyrinthina mirabilis Weynschenk.* The Micropaleontologist, vol. 8, no. 3, p. 47.

1956 – *Aulotortus, a new genus of foraminifera from the Jurassic of Tyrol, Austria.* Cushman Found. Foram. Res., Contr., vol. 7, pt. 1, pp. 26-28, pl. 6, tfs. 1-2.

ABSTRACT: *Fluctuations of North Atlantic surface-water temperatures during the Pleistocene are demonstrated by the patterns of occurrence in deep-sea cores of foraminifera that are known temperature-indicators. Similar patterns of occurrence have been found in three cores studied.*

North Atlantic planktonic foraminifera as Pleistocene temperature-indicators

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INTRODUCTION

In order to determine the distribution of planktonic foraminifera that are indicators of warm surface water, ninety-nine samples from three deep-sea cores were examined extensively for organic content. The cores were obtained originally by Dr. W. Maurice Ewing of the Lamont Geological Observatory, Columbia University, New York. Cores and sample material are presently located at the Observatory. Data on the three cores are presented in Table 1.

METHODS

The following procedure was employed: The cores were cut in half lengthwise and examined to ascertain that the original stratification remained undisturbed, and the length was carefully measured. Samples about 0.5 cubic inch in size were taken approximately every 20 cm. (or less if gross examination showed a possible change in the nature of the sediment) along the entire length of each core. The material from the outer edges was discarded in all cases, since it usually was contaminated by foreign material because of friction as the metal cylinder passed through the sediments. The shells in each sample were washed and caught on a 200-mesh sieve, through which finer particles of mud, clay, and smaller and fragmented organisms passed. The residual material was examined, and charts were drawn up showing the distribution of the temperature-indicating planktonic foraminifera contained in each core (Tables 2-4).

An earlier study (Kane, 1953), in which material from thirty-five North Atlantic localities was examined, showed that fifteen species of planktonic foraminifera can be considered indicators of warm surface water. Nine species (Group A) are indicative of mean annual surface-water temperatures of 20° C. or higher when they are either common or abundant:

Group A

Candeina nitida (d'Orbigny)
Globigerina trilocularis d'Orbigny
Globigerinoides conglobatus (Brady)
Globorotalia gibba (d'Orbigny)
Globorotalia menardii (d'Orbigny)
Globorotalia puncticulata (d'Orbigny)
Globorotalia tumida (Brady)
Pulleniatina obliquiloculata (Parker and Jones)
Valvulineria plummerae Loetterle

Six species (Group B) are indicative of mean annual surface-water temperatures of 20° C. or higher only when they are abundant:

Group B

Globigerina dubia Egger
Globigerinoides sacculifer (Brady)
Globorotalia hirsuta (d'Orbigny)
Globorotalia humilis (Brady)
Globorotalia truncatulinoides (d'Orbigny)
Orbulina universa d'Orbigny

Other planktonic species (Group C) occurred with varying frequencies throughout the cores. None of these species was found to be a reliable temperature-indicator, and for this reason they have been omitted from the present study:

micropaleontology, vol. 2, no. 3, pp. 287-293, text-fig. 1, tables 1-5, july, 1956

Group C

Globigerina bulloides d'Orbigny
Globigerina bulloides borealis Brady
Globigerina cf. *cretacea* d'Orbigny
Globigerina cf. *diplostoma* Reuss
Globigerina inflata d'Orbigny
Globigerinella aequilateralis (Brady)
Globigerinoides ruber (d'Orbigny)
Globorotalia scitula (Brady)
Hastigerina pelagica (Brady)
Laticarinina pauperata (Parker and Jones) (meroplanktonic)
Sphaeroidinella dehiscens (Parker and Jones)

Distribution of the foraminifera of Group C did not follow any specific or correlative pattern except for a general overall parallelism of distribution among all three groups in Core 19.

In order to facilitate the graphic presentation of evidence of temperature fluctuation during the Pleistocene epoch, relative temperature-values were assigned to the warm-water indicators of Groups A and B according to their frequencies (common or abundant) in any one sample. These values were based on four possible combinations of four factors: Presence in Group A, presence in Group B, occurrence as abundant, and occurrence as common.

The relative temperature-values chosen for the four possibilities were:

FREQUENCY AND GROUP	RELATIVE TEMPERATURE-VALUE
Abundant — Group A	9
Common — Group A	3
Abundant — Group B	3
Common — Group B	1

Thus, a species of Group A may have a relative temperature-value of 9 in one sample, when abundant, and of 3 in another, when common. Similarly, a species of Group B may have a relative temperature-value of 3 in one sample, when abundant, and of 1 in another, when common.

These values were selected in the belief that they best represent the relationship between organisms and temperature. Other ecologic factors, such as salinity, light, depth, current, presence of other organisms, and dissolved materials, are also involved in the occurrence of planktonic foraminifera, but temperature appears to be the major factor for the fifteen species concerned. It should be noted that while the values are arbitrary, they are consistent in equating a species of Group A that is common with a species of Group B that is abundant. This conforms with findings on present-day foraminifera that are temperature-indicators, which show that the common species of Group A are approximately equivalent to the abundant species of Group B in their tendency to occur at localities having mean annual surface-water temperatures of over 20° C. (Kane, 1953).

The rare occurrence of a species in a sample was not deemed of sufficient importance to warrant its inclusion as an indicator, nor were relative values assigned to such occurrences, because of the fortuity surrounding the presence of rare specimens in samples.

The combined relative values of all the indicators in each sample were added cumulatively to give a total relative value for the sample. Total values were computed for each sample in each core, and these were then plotted against the length of the core (centimeter distances below sea bottom, representing Pleistocene

TABLE 1

CORE DATA

	CORE 19	CORE 20	CORE 32
Location	34°36′ N., 46°19′ W.	35°07′ N., 44°40′ W.	44°21′ N., 30°16′ W.
Length	783 cm.	590 cm.	583 cm.
Surface-water temperature	21.6° C.	21.3° C.	16.3° C.
Surface-water salinity (from Trask, 1937)	36.6 ‰	36.5 ‰	35.9 ‰
Water depth	4627 meters	4334 meters	2752 meters
Number of samples studied	38	34	27

TABLE 2

CORE 19 — DISTRIBUTION CHART

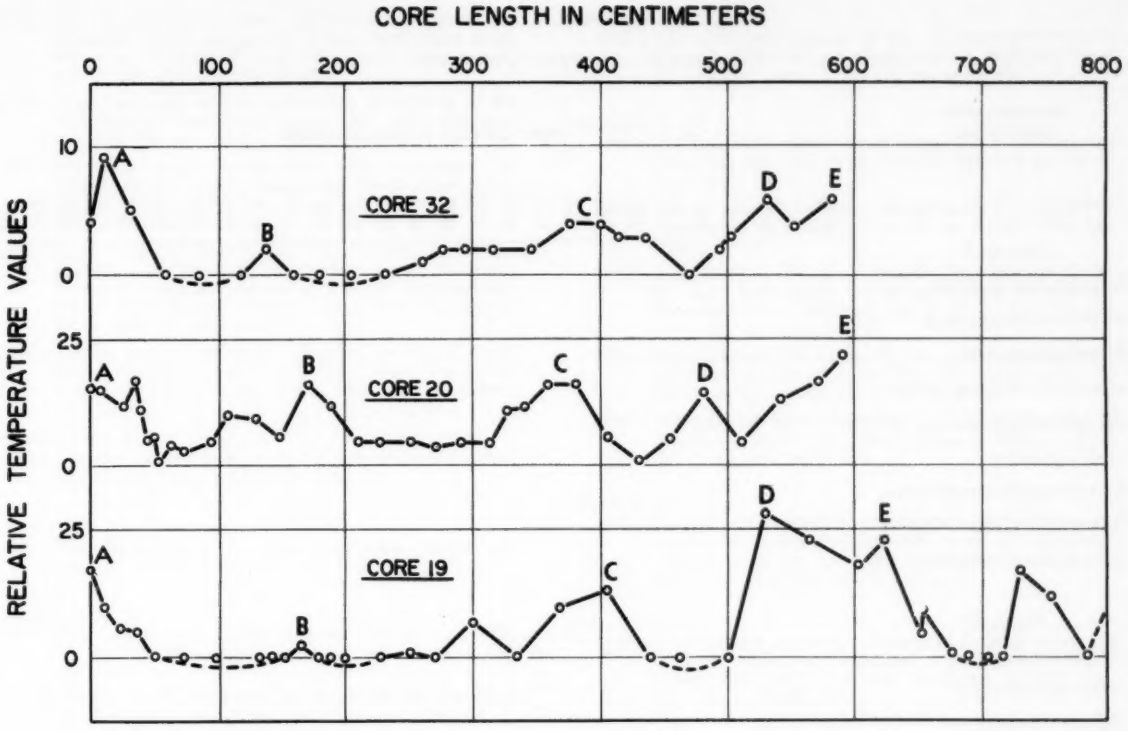
| TEMPERATURE INDICATORS | CORE LENGTH IN CENTIMETERS | | |

TABLE 3

CORE 20 — DISTRIBUTION CHART

TEMPERATURE INDICATORS	CORE LENGTH IN CENTIMETERS																																
	Top	7	25	35	40	45	49	53	63	73	94	108	130	148	170	189	210	228	250	270	290	312	327	340	359	380	407	430	456	482	511	542	572	590
Group A																																		
Globorotalia menardii		•																																
Valvulineria plummerae	•	×	×	×	×	•	×	•			•	•	•	•	•			•					•		•	•						•	×
Globorotalia tumida	•	•	•	•																•		•	×	×	×	×	•			•	•	•	×	×
Pulleniatina obliquiloculata	•	•	•	•	•											•				•	•	•		•	×	×	•			•	•		•	•
Globigerina trilocularis	×	×	×	×	•	•	•	•				•			×	•	•				•	•	•	•	•	×	•	•	•	•	•	×	×	×
Candeina nitida	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	•	•	•			•	•	•	×	×	•	•	×	×	×	×	×
Globigerinoides conglobatus	×	•	•	•	•	•		•	•			×	×	•	×	×	•	•			•	•	×	×	×	×	•	•	×	×	•	•	×	•
Globorotalia gibba	•	×	•	×	•			•				•	•	•	•	•	•	•		•	•	•	•	•	•	•	•					×	•	×
Globorotalia puncticulata																																		
Group B																																		
Globigerina dubia	•		•	•	•		•	•			•	×	×	×	×	×	•	×	×	×	×	×	•	×	•	•	•	•	•	•	•	•		•
Globorotalia humilis	×	×	×	●	●	×	•	×	×	•	×	×	×	×	●	●	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Orbulina universa	•	•		•	•	•				•	•				×	•	•		×	•	•	×	×	×	×	×	•	•	×	×		•	×	×
Globorotalia hirsuta	●	×	×	×	×	•		•	•				•	•	•	•	•	×	×	×	×	×	×	×	×	×	×	•	×	×	×	×	×	×
Globorotalia truncatulinoides	×	×	×	×	×	×	•	•	•	•	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		•	×	•	×	×	●
Globigerinoides sacculifer	×	•	•	•	•	•	•	•	•			×	•	•	×	×	•	×		•	×	•	×	×	×	×	×	•	•	×	•	×	×	×
RELATIVE TEMPERATURE VALUES	15	15	12	17	11	5	6	1	4	3	5	10	9	6	16	12	5	5	5	4	5	5	11	12	17	17	7	1	6	14	5	13	17	22

Symbols: ● = abundant; × = common; • = rare.



TEXT-FIGURE 1

Pleistocene temperature fluctuations as measured by relative temperature-values of planktonic foraminifera occurring in North Atlantic deep-sea cores.

time) in text-figure 1. Results obtained from these graphs should be viewed as indicative rather than definitive. Trends as shown on the graphs are regarded as significant only when correlation is possible between the three cores.

RESULTS

Comparison of the curves in text-figure 1 reveals similar patterns of fluctuation of relative temperature-values in all three cores. The magnitudes of the fluctuations are similar in Cores 19 and 20 but are smaller in Core 32, perhaps because the latter was taken from an area that is far to the northeast of the other two and that has a much colder present-day mean annual surface-water temperature. Positions A, B, C, D, and E are highs that show close correlation between the three curves, while the intervening lows (A–B, B–C, C–D, and D–E) also occupy similar positions in relation to the length of the cores. Further sampling is, of course, desirable, in order to smooth out the sharp angles in the curves and to add more points on the highs. Table 5 shows the close correlation between the highs in the three cores:

TABLE 5

APPROXIMATE LOCATION OF HIGHS RELATIVE TO POSITION IN CORE

HIGH	LOCATION (CENTIMETERS FROM TOP)		
	Core 32	Core 19	Core 20
A	Top	Top	Top
B	140	170	170
C	390	400	370
D	530	530	480
E	580	620	590

Although additional sampling is considered necessary in order to provide more points around High B in Cores 19 and 32, it is believed to be a positive high, since it is present in all three cores at about the same position. Also, while High E is a definite peak in Core 19, it represents merely a high area at the extreme lower limit of Cores 20 and 32, so that the actual peak may have occurred somewhat lower, at an earlier time.

TABLE 4

CORE 32 — DISTRIBUTION CHART

TEMPERATURE INDICATORS	CORE LENGTH IN CENTIMETERS																												
	Top	7	30	58	84	117	137	157	158	179	203	230	260	276	293	315	345	375	400	412	435	470	492	501	532	552	583
Group A																											
Globorotalia menardii																		·							·		
Valvulineria plummerae	·	·																									
Globorotalia tumida		·																									
Pulleniatina obliquiloculata			·																								
Globigerina trilocularis		·	·			·	·														·						
Candeina nitida	·	×	×		·	·		·		·		·				·		·	·	·	·			·	·		·
Globigerinoides conglobatus	·	·																	·	·	·						
Globorotalia gibba		·																									
Globorotalia puncticulata																							·				
Group B																											
Globigerina dubia			·	·				·												·	·			·		·	
Globorotalia humilis	×	●	×	·	·	·	×	·		·	·	·	×	×	×	×	×	×	×	×	×	·	·	×	●	×	●
Orbulina universa	×	×	×			·	·	·		·		·	·	×	×	×	·	×	×	·	·	·	×	·	×	×	×
Globorotalia hirsuta	×	×	·					·		·		·		·	·		·	×	×	×	×	·	·	×	×	×	×
Globorotalia truncatulinoides	×	×	·			·	×		·	·		·			·	·	×	×	×	×	×	·	×	×	×	×	×
Globigerinoides sacculifer	·	·																									
RELATIVE TEMPERATURE VALUES	4	9	5	0	0	0	2	0	0	0	0	0	1	2	2	2	2	4	4	3	3	0	2	3	6	4	6

Symbols: ● = abundant; × = common; · = rare.

Since the zero point on a graph merely indicates absence of warm-water indicators, no proportional measurements of temperature are possible below that point. For this reason, dotted lines are drawn below the zero line to illustrate probable relationships.

No attempt was made to interpret actual temperatures in degrees Centigrade from the relative temperature-values indicated by the foraminifera. Additional research on living planktonic organisms will be necessary before this can be accurately accomplished. Furthermore, no attempt is made here to relate actual time in numbers of years to the core lengths. For that purpose, additional data, possibly including radioactive measurements, would be necessary. The correlation of core fluctuations with Pleistocene glacial and interglacial stages is therefore left to future reports.

CONCLUSIONS

Pleistocene temperature fluctuations of North Atlantic surface waters can be measured by plotting the distribution in long deep-sea cores of planktonic foraminifera that are known to be warm-water indicators. Similarity of fluctuation patterns is evident in the three cores studied. The fluctuations may be correlative with advances and retreats of Pleistocene continental glaciers, or with recurrent shifting of warm and cool ocean-surface currents, the latter perhaps being manifestations of the former.

BIBLIOGRAPHY

BRADY, H. B.
1877 – *Supplementary notes on the foraminifera of the Chalk(?) of the New Britain Group.* Geol. Mag., new ser., decade 2, vol. 4, pp. 534-536.

1878 – *On the reticularian and radiolarian Rhizopoda (foraminifera and polycystina) of the North-Polar Expedition of 1875-1876.* Ann. Mag. Nat. Hist., ser. 5, vol. 1, pp. 425-440, pls. 20-21.

1879 – *Notes on some of the reticularian Rhizopoda of the "Challenger" Expedition.* Quart. Jour. Micr. Sci., new ser., vol. 19, pp. 20-63, 261-299, pls. 3-5.

1881 – *On some Arctic foraminifera from soundings obtained on the Austro-Hungarian North-Polar Expedition of 1872-1874.* Ann. Mag. Nat. Hist., ser. 5, vol. 8, pp. 393-418, pl. 21.

1882 – *Report on the foraminifera.* In: TIZARD, Staff-Commander, and MURRAY, J., *Exploration of the Faroe Channel during the summer of 1880, in Her Majesty's hired ship "Knight Errant."* Roy. Soc. Edinburgh, Proc., vol. 11, pp. 708-717.

1884 – *Report on the foraminifera dredged by H.M.S. Challenger during the years 1873-1876.* Rept. Voy. Challenger, Zool., vol. 9, pp. 1-814, pls. 1-115 (in atlas).

CARPENTER, W. B.
1862 – *Introduction to the study of the foraminifera.* London: Ray Society, pp. 1-319, pls. 1-22.

CHAPMAN, F.
1902 – *The foraminifera.* London: Longmans, Green and Co., pp. 1-354, pls. 1-14, tfs. 1-42.

CUSHMAN, J. A.
1931 – *The foraminifera of the Atlantic Ocean; Part VIII.* U. S. Nat. Mus., Bull., no. 104, pt. 8, pp. 1-179, pls. 1-26.

1941 – *A study of the foraminifera contained in cores from the Bartlett Deep.* Amer. Jour. Sci., vol. 239, no. 2, pp. 128-147, pls. 1-6, tfs. 1-10.

CUSHMAN, J. A., AND HENBEST, L. G.
1940 – *Foraminifera.* In: *Geology and biology of North Atlantic deep-sea cores between Newfoundland and Ireland.* U. S. Geol. Survey, Prof. Paper no. 196-A, pp. 35-54, pls. 8-10, tfs. 11-21.

DESHAYES, G. P.
1832 – *Encyclopédie méthodique, Histoire naturelle des Vers.* Paris: Mme. v. Agasse, vol. 2, pt. 2, 594 pp.

EGGER, J. G.
1857 – *Die Foraminiferen der Miocän-Schichten bei Ortenburg in Nieder-Bayern.* Neues Jahrb. Min., Geogn., Geol., Petref.-Kunde, pp. 266-311, pls. 1-15.

ELLIS, B. F., AND MESSINA, A.
1940 *et seq.* – *Catalogue of foraminifera.* American Museum of Natural History, Spec. Publ., 30 vols. and supplements, ill.

FLINT, J. M.
1899 – *Recent foraminifera.* U. S. Nat. Mus., Ann. Rept. (1897), pt. 1, pp. 249-349, pls. 1-80.

FORNASINI, C.
1897 – *Le sabbie gialle bolognesi e le ricerche di J. B. Beccari.* R. Accad. Sci. Ist. Bologna, Rend., new ser., vol. 2 (1897-1898), fasc. 1, pp. 9-14, 1 pl., 1 tf.

1898 – *Le globigerine fossili d'Italia.* Pal. Italica, vol. 4, pp. 203-216, tfs. 1-5.

KANE, J.
1953 – *Temperature correlations of planktonic foraminifera from the North Atlantic Ocean.* Micropaleontologist, New York, vol. 7, no. 3, pp. 25-50, pls. 1-3.

LOETTERLE, G. J.
1937 – *The micropaleontology of the Niobrara formation in Kansas, Nebraska and South Dakota.* Nebraska Geol. Survey, Bull., ser. 2, no. 12, pp. 9-73, pls. 1-11.

ORBIGNY, A. D'
1826 – *Tableau méthodique de la classe des Céphalopodes.* Ann. Sci. Nat., vol. 7, pp. 96-169, 245-314, pls. 10-17 (in atlas).

1839 – *Voyage dans l'Amérique Méridionale; Foraminifères.* Strasbourg: P. Bertrand, vol. 5, pt. 5, pp. 1-86, pls. 1-9.

1839 – *Foraminifères des îles Canaries.* In: BARKER-WEBB, P., AND BERTHELOT, S., *Histoire naturelle des îles Canaries.* Paris: Bethune, vol. 2, pt. 2, pp. 119-146, pls. 1-3.

1839 – *Foraminifères.* In: SAGRA, R. DE LA, *Histoire physique, politique et naturelle de l'île de Cuba.* Paris: A. Bertrand, pp. 1-244, pls. 1-12 (in atlas).

1840 – *Mémoire sur les foraminifères de la Craie Blanche du Bassin de Paris.* Soc. Géol. France, Mém., vol. 4, no. 1, pp. 1-51, pls. 1-4.

OVEY, C. D.
1950 – *On the interpretation of climatic variations as revealed by a study of samples from an Equatorial Atlantic deep-sea core.* Roy. Meteorol. Soc., Centenary Proc., London, pp. 211-215, ill.

PARKER, F. L.
1948 – *Foraminifera from the Continental Shelf from the Gulf of Maine to Maryland.* Harvard Coll., Mus. Comp. Zoöl., Bull., vol. 100, no. 2, pp. 213-241, pls. 1-7, tfs. 1-4, tables.

PARKER, W. K., AND JONES, T. R.
1865 – *On some foraminifera from the North Atlantic and Arctic Oceans.* Roy. Soc. London, Philos. Trans., vol. 155, pp. 325-441, pls. 13-19.

PHLEGER, F. B
1939 – *Foraminifera of submarine cores from the Continental Slope.* Geol. Soc. Amer., Bull., vol. 50, pp. 1395-1422, pls. 1-3, tfs. 1-4, tables.

1942 – *Foraminifera of submarine cores from the Continental Slope; Part 2.* Geol. Soc. Amer., Bull., vol. 53, pp. 1073-1098, pls. 1-3 (tables), tfs. 1-6, table 1.

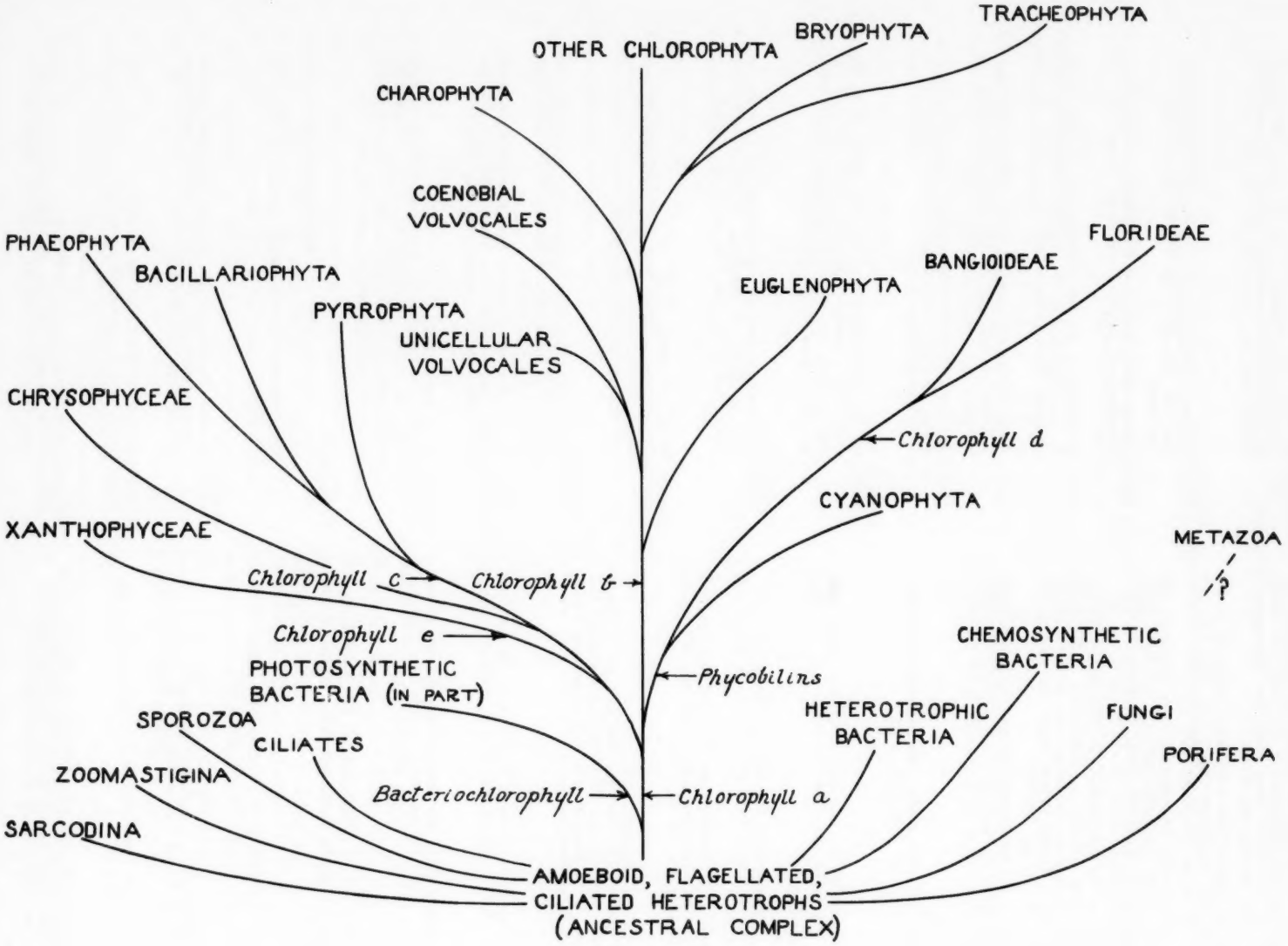
PHLEGER, F. B, AND PARKER, F. L.
1951 – *Ecology of foraminifera, northwest Gulf of Mexico.* Geol. Soc. Amer., Mem., no. 56, pt. 1 (*Foraminifera distribution*), pp. 1-88, pls. 1-2, tfs. 1-33, tables 1-37; pt. 2 (*Foraminifera species*), pp. 1-64, pls. 1-20.

REUSS, A. E.
1850 – *Neue Foraminiferen aus den Schichten des österreichischen Tertiärbeckens.* K. Akad. Wiss. Wien, Math.-Naturw. Cl., Denkschr., vol. 1, pp. 365-390, pls. 46-51.

TRASK, P. D.
1937 – *Relation of salinity to the calcium carbonate content of marine sediments.* U. S. Geol. Survey, Prof. Paper no. 186-N, pp. 273-299, 1 pl., 8 tfs.

U. S. HYDROGRAPHIC OFFICE
1944 – *World atlas of sea-surface temperatures.* Ed. 2. U. S. Hydrographic Office, Publ., Washington, D. C., no. 225.

WISEMAN, J. D. H., AND OVEY, C. D.
1950 – *Recent investigations on the deep-sea floor.* Geologists' Assoc., Proc., vol. 61, pt. 1, pp. 28-84, ill.



TEXT-FIGURE 1

PHYLOGENETIC SCHEMA WITH SPECIAL REFERENCE TO THE ALGAE

Evaluation of the Protista as a group of living organisms

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EDITORS' NOTE: *This note is a condensation of one of ten papers presented at a round-table program on plant-microfossil systematic methods to which the Paleobotanical Section of the Botanical Society of America devoted one day of its annual meeting at East Lansing, Michigan, in September, 1955. Other papers presented at this round-table program will be published in future numbers of this quarterly.*

The idea of classifying organisms into more than two kingdoms, although not new, has received only scattered support. Recently, Moore (1954) argued for the adoption of a third kingdom, the Protista, to include "all acellular organisms" (bacteria, fungi, algae, and protozoa). The point of view in the following critique of Moore's proposal is that of a student of living organisms.

Moore's arguments are as follows: (1) Among the various groups of acellular organisms that are simultaneously classified as animals by zoologists and as plants by botanists because of intergrading characters, interrelationships outweigh differences; hence, they should be retained in their own kingdom to avoid arbitrary assignment to either the animal or the plant kingdom; (2) the acellular level of organization is peculiar to and characteristic of these groups. Moore subdivides the Protista into two subkingdoms: the Monera, lacking "a definitely developed nucleus"; and the Protoctista, with "a distinct nucleus."

In my opinion, the fact that a vast number of organisms exhibit characters not wholly animal-like or plant-like suggests that phylogeny would best be expressed within a single kingdom. For practical purposes, however, the recognition of two kingdoms seems justified. Recognition of more than two kingdoms necessitates more violence to phylogenetic relationships and a greater degree of arbitrariness than does recognition of two kingdoms.

The character unifying the Protista as a taxonomic group, according to Moore, is their acellular organization, which he defines as the possession "within a single cell [of] total properties of life which may reproduce itself; the body does not require an organized arrangement of differentiated, mutually interdependent cells." The fallaciousness of this premise becomes apparent when one considers the morphological complexity of multicellular algae, especially the Charophyta, most Rhodophyta, and most Phaeophyta. The kelps are well known for their high degree of internal differentiation, exhibiting some sort of vascular tissue and localized meristems giving rise to both primary (longitudinal) and secondary (radial) growth.

Placing the Chlorophyta in a kingdom separate from the Embryophyta scarcely seems justifiable. The points of difference (namely, multicellular rather than unicellular sex organs, and the presence or absence of embryos) shrink in importance when compared with the following fundamental similarities between the two groups: (1) identical complement of photosynthetic pigments; (2) identical metabolites; (3) identical basic structure and manner of insertion of flagella.

Similar difficulties would be encountered in attempting to separate the Monera from the Protoctista. Current studies with the electron microscope have provided evidence that bacteria and blue-green algae have nuclear equivalents. Moreover, the Cyanophyta are so closely related to the Rhodophyta as to fail to justify separation at such a high level. The absence of flagellated reproductive cells and the presence of a distinctive group of photosynthetic pigments, the phycobilins, are two important phylogenetic ties. Indeed, the more primitive red algae, such as the unicellular *Porphyridium*, are intermediate in certain respects (for example, the particular kind of phycobilin) between the reds and the blue-greens.

The schema (text-fig. 1) summarizes my ideas on phylogeny. It is interesting to note that the algae fall into three superphyla or primary phyletic lines, namely, the chlorophyll $a-b$ line, the chlorophyll $a-c-e$ line, and the chlorophyll $a-d$ line.

BIBLIOGRAPHY

MOORE, R. C.
1954 – *Kingdom of organisms named Protista.* Jour. Pal., vol. 28, no. 5, pp. 588-598, tables 1-5.

micropaleontology, vol. 2, no. 3, pp. 294-295, text-fig. 1, july, 1956

notes and comment

Ten rules concerning the nomenclature and classification of the foraminifera

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In recent years, no other fossil group has been the subject of so many publications as have the foraminifera. According to Thalmann (1952, and his bibliography appearing annually in the Journal of Paleontology), a total of 8218 publications appeared from 1931 to the end of 1953, which contained 673 new generic and 9067 new specific names. The Catalogue of Foraminifera (Ellis and Messina, 1940 *et seq.*) now contains almost 2000 generic and about 25,000 specific names.

It has frequently been asked: "Where does this sizable production of new taxonomic units lead to? Are all these new names necessary for the progress of foraminiferology?" (Thalmann, 1952, p. 145). A good answer can be found in Höglund's painstaking study of the foraminifera of the Skagerak: ". . . the taxonomy [of the foraminifera] is unfortunately in a state of extreme confusion" (Höglund, 1947, p. 16). This statement is equally applicable to both Recent and fossil foraminifera. Hiltermann (1954, p. 385) remarks that the situation in many fossil groups has come to the point where a stratigraphic geologist can no longer either read or use fossil lists because, in different parts of the world, synchronous species only very infrequently bear the same name.

Because of the continuously increasing number of names, and especially generic names, paleontological nomenclature is becoming unstable and increasingly less useful. M. Weller (1949) therefore suggests that new names of "current genera" be given only subgeneric rank, and that their use should be left to specialists only; these names could be ignored by all other paleontologists. Nevertheless, it must be emphasized that there can be only one system of taxonomy and nomenclature, which is valid for all workers. "Both the biologist and the paleontologist must diagnose their species and genera on the basis of morphological characters" (Wright, 1950, p. 747). In connection with the foraminifera, paleontology is in the fortunate position of being able to follow this requirement, for the characters used in taxonomy are equally applicable to both Recent and fossil foraminifera.

It has been repeatedly stated by both biologists and paleontologists that the cardinal point in any system of classification is the species-concept (see Hiltermann, 1954). The species is the basic category of biological systematics because it is the category that deals the most directly with the actual objects, and that therefore provides the greatest number of characters. The genus, together with the higher categories, is a function of the species-concept. Beginning with the genus, it is up to the subjective judgment of each worker which of the objectively available specific characters he wishes to use in these higher groupings. The idea that the species possesses the highest degree of objectivity is well illustrated by the fact that in most living organisms the morphologic species-concept coincides with the physiological species-concept.

Population studies are invaluable in the description of a species (see, among others, Glaessner, 1955; Hiltermann, 1951; Remane, 1937; Wright, 1950). All the organic and inorganic factors should be taken into account, in order to attain greater stratigraphic and bionomic accuracy in the reconstruction of fossil biotopes. Statistical analyses and representations of the characters and their ranges of variation provide an objective basis for the description of species. However, in the case of the foraminifera, instead of such analyses based on large numbers of specimens, only relatively short descriptions of the various forms have been given. It has therefore been impossible to consider questions of zoogeography and regional ecology, for adequate descriptions and differentiation of intraspecific units are not yet available.

Recent works on fossil foraminifera show that these methods are also more useful in biostratigraphy than the formerly customary methods of species-naming and species-differentiation. For example, in the Oligo-Miocene of Trinidad there were formerly believed to be a large number of distinct species of *Globorotalia*. Bolli (1950, p. 84) has shown, however, that they belong to a single phyletic series, extending from *Globorotalia fohsi barisanensis* to *Globorotalia fohsi robusta*. Similarly, there were formerly believed to be a number of distinct species of *Bolivinoides* in the Upper Cretaceous of England, Germany, Poland and Scandinavia, and of Israel, Australia and North America. Hiltermann and Koch (1950) have recently demonstrated that these species constitute two phyletic series, one extending from *Bolivinoides strigillata* to *Bolivinoides decorata gigantea*, and the other from *Bolivinoides strigillata* to *Bolivinoides draco draco*.

In every foraminiferal group, such synthesizing studies, based on a large amount of material from all parts of the world, should follow the analytical phase that has prevailed until the present time. Because of their frequent occurrence, their wide distribution and their good preservation, the foraminifera are highly suitable for studies of this sort. In order to make them truly worldwide guide fossils, and in order to discover the principles of their geographic and ecologic distribution, it is suggested that the following ten rules be observed:

1) New specific names should be published only when the worker has specimens of related species available, so that the omissions that are unavoidable in every description and illustration can be compensated for by direct study. If the original type specimens are lost, the use of the old name with a new description based on a neotype is preferable to comparison with the former description alone.

2) A new specific name is often a means of avoiding a taxonomic decision. In case of doubt, it is preferable to use open nomenclature or an optional subspecific name.

3) It is absolutely necessary to furnish a clear and unequivocal type-definition with a differential diagnosis and delimitation from related types. In addition, the position of the type specimen of the species in the binominal curve must be stated, without fail.

4) The number of specimens studied should always be given. It should become customary, at least in micropaleontology, to collect at least ten specimens before a new species is established.

5) Graphic statistical representation and evaluation of the characters provide comparable objective values to a degree that cannot be attained in a verbal definition.

6) As many characters as possible should be described, and their interrelations should be studied. In actual practice, it will be, for the most part, impossible to publish all the measurements, although the latter are the primary factors in the evaluation and selection of taxonomically important characters.

7) Monographic revisions of individual species should be made, using all the methods of biology, especially variation-statistics and the study of zoogeographic and biozonologic data.

8) The International Rules of Zoological Nomenclature should be applied to their fullest extent as the basis of all new species published. In this connection, the rule concerning adequate description and illustration is very important (see Point 3).

9) A simple photograph of the holotype is seldom sufficient as an illustration of a new species. Photographs and drawings, not only of the holotype, but also of the paratypoids, show the individual characters much better.

10) Synonym lists should be compiled as critically as possible, and should represent not merely a list of identical *names*, but a list of identical *forms*. Generally speaking, therefore, names given in the literature without further details do not belong in synonym lists.

BIBLIOGRAPHY

Only papers referred to above are listed here. Further references will be found in Hiltermann (1954).

ARNOLD, Z. M.
1953 – *Paleontology and the study of variation in living foraminifera.* Cushman Found. Foram. Res., Contr., vol. 4, pt. 1, pp. 24-26, pl. 3.

BOLLI, H.
1950 – *The direction of coiling in the evolution of some Globorotaliidae.* Cushman Found. Foram. Res., Contr., vol. 1, pt. 3-4, pp. 82-89, pl. 15, text-figs. 1-5, tables 1-2.

ELLIS, B. F., AND MESSINA, A. R.
1940 *et seq.* – *Catalogue of foraminifera.* New York: American Museum of Natural History, Spec. Publ., 30 vols. and supplements, ill.

GLAESSNER, M. F.
1955 – *Taxonomic, stratigraphic and ecologic studies of foraminifera, and their interrelations.* Micropaleontology, vol. 1, no. 1, pp. 3-8.

HILTERMANN, H.
1951 – *Populationen in ihrer Bedeutung für die Paläontologie und Stratigraphie.* Erdöl und Kohle, vol. 4, no. 5, pp. 244-249, text-figs. 1-3.

1954 – *Zur Artfassung in der Paläontologie.* Roemeriana, vol. 1, pp. 385-392.

HILTERMANN, H., AND KOCH, W.
1950 – *Taxonomie und Vertikalverbreitung von Bolivinoides im Senon NW-Deutschlands.* Geol. Jahrb., vol. 64, pp. 595-632, 7 text-figs., 7 graphs, 7 tables.

HÖGLUND, H.
1947 – *Foraminifera in the Gullmar Fjord and the Skagerak.* Uppsala, Univ., Zool. Bidrag, vol. 26, pp. 3-328, pls. 1-32, text-figs. 1-312, 7 tables, 2 maps.

REMANE, A.
1937 – *Populationsforschung, eine notwendige Forschungsrichtung für die Systematik.* Entomol. Ges. Halle a. S., Mitt., no. 15, pp. 3-19.

RENSCH, B.
1938 – *Some problems of geographical variation and species-formation.* Linnean Soc. London, Proc., Sess. 150, pp. 275-285.

SIMPSON, G. G., AND ROE, A.
1939 – *Quantitative zoology; Numerical concepts and methods in the study of Recent and fossil animals.* New York: McGraw-Hill, 414 pp.

THALMANN, H. E.
1947 – *Bemerkungen zur Foraminiferen-Literatur der letzten Jahre.* Eclogae Geol. Helv., vol. 39 (1946), no 2, pp. 379-384.

1949 – *Probleme der Mikropoläontologie.* Eclogae Geol. Helv., vol. 41 (1948), no. 2, pp. 372-375.

1952 – *Twenty years of "foraminiferal statistics": 1931 to 1950.* Cushman Found. Foram. Res., Contr., vol. 3, pt. 3-4, pp. 145-146.

WELLER, J. M.
1949 – *Paleontologic classification.* Jour. Pal., vol. 23, no. 6, pp. 680-690, text-figs. 1-4.

WRIGHT, C. W.
1950 – *Paleontologic classification.* Jour. Pal., vol. 24, no. 6, pp. 746-748.

Triletes palaeocristatus Chaloner, new name

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In 1954 the author published a description of a number of lycopod megaspores from the Mississippian rocks of the northeastern United States. These included *Triletes cristatus* Chaloner (Chaloner, 1954, p. 29). This combination was, however, used earlier by Dijkstra (1949) for a Senonian megaspore from Holland. The Mississippian and Senonian spores are quite clearly distinct species. Dijkstra's name has priority, and I therefore propose the following new name for the Mississippian spore:

Triletes palaeocristatus Chaloner, **new name**

Triletes cristatus CHALONER, 1954, p. 29, pl. 2, figs. 5-6 (non *Triletes cristatus* DIJKSTRA, 1949, p. 23, pl. 1, fig. 3).

Diagnosis and holotype: As cited for *Triletes cristatus* Chaloner (1954, p. 29).

I wish to express my thanks to Mr. M. P. Schemel of the West Virginia Geological Survey for drawing my attention to this unfortunate error.

BIBLIOGRAPHY

CHALONER, W. G.
1954 – *Mississippian megaspores from Michigan and adjacent states.* Michigan, Univ., Mus. Pal., Contr., vol. 12, no. 3, pp. 23-35, pls. 1-2, tf. 1.

DIJKSTRA, S. J.
1949 – *Megaspores and some other fossils from the Aachenian (Senonian) in South Limburg, Netherlands.* Netherlands, Geol. Stichting, Meded., new ser., no. 3 (1948-1949), pp. 19-32, pls. 1-2.

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Garrett, J. B., Jr.
Overton, C. K.
Parks, J. W.
Petrusek, B. J.
Phillips, H. H.
Ray, S. W.
Setzer, F. M.
Traylor, J. C.
Texas Gulf Producing Co., Box 2199
Chun, H. A.
Union Oil Co. of California, 800 Prudential Bldg.
Hohman, R. E.
Stuckey, C. W., Jr.
Wardell, J. W.
Union Producing Co., Box 2492
Mornhinveg, A. R.
MCALLEN
Sun Oil Co., Box 1270
Means, J. A.
MIDLAND
Paleontological Lab., Box 51
Arant, W. H.
Davis, B. G.
Hollingsworth, R. V.
Williams, H. L.
Shell Oil Co.
Sanderson, G. A., Jr.
Vogler, E. A.
PALESTINE
Carter-Gragg Oil Co., Carter-Gragg Bldg.
Tillman, D. M.
RICHARDSON
Sun Oil Co., 503 North Central Express
Cordell, R. J.
Hamilton, I. B.
Schell, W. W.
Shaw, W. G.
SAN ANTONIO
Amerada Oil Co., 1414 National Bank of Commerce Bldg.
Horton, E. H.
Magnolia Petroleum Co., 1704 Alamo National Bldg.
Sandidge, J. R.
Standard Oil Co. of Texas, 149 South Main Ave.
Tartamella, N. J.
Sun Oil Co., 832 Milam Bldg.
Beemer, E. F., Jr.
TYLER
Humble Oil & Refining Co., Box 2025
Raasch, A. C.
Shell Oil Co., Box 2037
Carter, A.
Hamberg, L. R.
Leigh, B.
Nichols, P. H.
Peters, T. C.
Terry, J. S.

This directory was closed in April, 1956. It is requested that omissions and corrections be brought to the attention of D. K. Cameron, Jr., The California Co., 800 The California Co. Bldg., New Orleans, Louisiana.

The types of Lamarck's genera of foraminifera as selected by J. G. Children in 1823

ALFRED R. LOEBLICH, JR.
U. S. National Museum
Washington, D. C.

In Volumes 14, 15 and 16 of the Quarterly Journal of Science, Literature and the Arts (1822-1824), there appeared six articles, published anonymously, on "Lamarck's genera of shells . . . ," in which type designations were made for many of Lamarck's genera, including the foraminifera. However, as these articles were published without citation of the author (who, in reality, was J. G. Children, the editor of the publication), they are invalid for use in fixing type designations.

In 1823, however, Children republished these articles separately, under the title of "Lamarck's genera of shells, translated from the French by J. G. Children with plates from original drawings by Miss Anna Children, 1823." Attention is here called to this rare but important work, inasmuch as it has been overlooked by all later workers on the foraminifera.

Kennard, Salisbury and Woodward (1931) published an article giving Children's type designations for mollusk genera, but they stated (1931, p. 2) that they were "omitting such forms as are now no longer included in the Mollusca. . . ." Later workers have not had access to the 1823 publication by Children because of its rarity. The designations of types other than those of mollusks have therefore been overlooked.

No mention is made of these early designations of types for genera of foraminifera in the comprehensive "Catalogue of Foraminifera" by Ellis and Messina (1940 *et seq.*), in Galloway's "Manual of foraminifera" (1933), or in any of the four editions of Cushman's "Foraminifera, their classification and economic use" (1928, 1933, 1940, 1948). This article by Children is clearly a publication, as regards availability for use, and there is no doubt that Children understood "type" in its modern sense.

In the reprint published under Children's name, there is separate pagination from 1 to 177, but there is a typographical error in one section — pages 123-153 are numbered 87-117, thus duplicating these numbers. Some of the designations of foraminiferal type species occur in this section.

No attempt is made here to decide whether the type designations made by Children in 1823 are valid or invalid. A simple list of the types that he designated for foraminiferal genera, and the page references to the reprint cited above, is presented.

Spirolinites Lamarck, 1804. Type: *Spirolinites cylindracea* Lamarck, 1804; subsequent designation by Children (1823, p. 115 [= 151]).

Lituolites Lamarck, 1804. Type: *Lituolites nautiloidea* Lamarck, 1804; subsequent designation by Children (1823, p. 116 [= 152]).

Cristellaria Lamarck, 1816. Type: *Cristellaria squammula* Lamarck, 1822; subsequent designation by Children (1823, p. 117 [= 153]).

Orbiculina Lamarck, 1816. Type: *Orbiculina numismalis* Lamarck, 1822; subsequent designation by Children (1823, p. 117 [= 153]).

Miliolites Lamarck, 1804. Type: *Miliolites cor anguinum* Lamarck, 1804; subsequent designation by Children (1823, p. 155).

Melonites Lamarck, 1812. Type: *Melonites sphaerica* Lamarck, 1816; subsequent designation by Children (1823, p. 155).

Rotalites Lamarck, 1801. Type: *Rotalites trochidiformis* Lamarck, 1804; subsequent designation by Children (1823, p. 156).

Lenticulites Lamarck, 1804. Type: *Lenticulites rotulata* Lamarck, 1804; subsequent designation by Children (1823, p. 156).

Placentula Lamarck, 1822. Type: *Placentula pulvinata* Lamarck, 1822; subsequent designation by Children (1823, p. 157).

Polystomella Lamarck, 1822. Type: *Polystomella crispa* (Linné) [= *Nautilus crispus* Linné, 1758]; subsequent designation by Children (1823, p. 158).

Vorticialis Lamarck, 1812. Type: *Vorticialis craticulata* (Fichtel and Moll) [= *Nautilus craticulatus* Fichtel and Moll, 1798]; subsequent designation by Children (1823, p. 158).

Orthocera Lamarck, 1799. Type: *Orthocera raphanus* (Linné) [= *Nautilus raphanus* Linné, 1758]; subsequent designation by Children (1823, p. 113 [= 149]).

Nodosaria Lamarck, 1812. Type: *Nodosaria radicula* (Linné) [= *Nautilus radicula* Linné, 1758]; subsequent designation by Children (1823, p. 113 [= 149]).

Discorbites Lamarck, 1804. Type: *Discorbites vesicularis* Lamarck, 1804; subsequent designation by Children (1823, p. 157).

Renulites Lamarck, 1804. Type: *Renulites opercularis* Lamarck, 1804; subsequent designation by Children (1823, p. 116 [= 152]).

Siderolites Lamarck, 1801. Type: *Siderolites calcitrapoides* Lamarck, 1801; subsequent designation by Children (1823, p. 158).

Nummulites Lamarck, 1801. Type: *Nummulites laevigata* (Bruguière) [= *Camerina laevigata* Bruguière, 1792]; subsequent designation by Children (1823, p. 159).

The writer is indebted to Mr. Graham Elliott, Iraq Petroleum Company, London, for bibliographic assistance and for checking page references in Children's article.

BIBLIOGRAPHY

ANONYMOUS
1822 – *Lamarck's genera of shells.* Quart. Jour. Sci., Lit. and Arts, London, vol. 14, no. 27, pp. 64-86, pls. 3-4.

1823 – *Lamarck's genera of shells (continued).* Ibid., vol. 14, no. 28, pp. 298-322, pls. 5-6.

1823 – *Lamarck's genera of shells (continued).* Ibid., vol. 15, no. 29, pp. 23-52, pls. 2-3.

1823 – *Lamarck's genera of shells (continued).* Ibid., vol. 15, no. 30, pp. 216-258, pls. 7-8.

1823 – *Lamarck's genera of shells (continued).* Ibid., vol. 16, no. 31, pp. 49-79, pl. 5.

1824 – *Lamarck's genera of shells (concluded).* Ibid., vol. 16, no. 32, pp. 241-264, pl. 6.

CHILDREN, J. G.
1823 – *Lamarck's genera of shells, translated from the French by J. G. Children with plates from original drawings by Miss Anna Children.* London: The author, pp. 1-177, 10 pls.

CUSHMAN, J. A.
1928 – *Foraminifera, their classification and economic use.* Cushman Lab. Foram. Res., Spec. Publ. no. 1, pp. 1-401, pls. 1-59.

1933 – *Foraminifera, their classification and economic use.* Ed. 2. Cushman Lab. Foram. Res., Spec. Publ. no. 4, pp. 1-349, pls. 1-29; Spec. Publ. no. 5, pls. 1-40.

1940 – *Foraminifera, their classification and economic use.* Ed. 3. Cambridge, Mass.: Harvard University Press, pp. 1-535, pls. 1-31; Key, pls. 1-48.

1948 – *Foraminifera, their classification and economic use.* Ed. 4. Cambridge, Mass.: Harvard University Press, pp. 1-605, pls. 1-31; Key, pls. 1-55.

ELLIS, B. F., AND MESSINA, A. R.
1940 *et seq.* – *Catalogue of foraminifera.* New York: Amer. Mus. Nat. Hist., Spec. Publ., 30 vols. and supplements, ill.

GALLOWAY, J. J.
1933 – *A manual of foraminifera.* Bloomington, Ind.: Principia Press, pp. 1-480, pls. 1-42.

KENNARD, A. S., SALISBURY, A. E., AND WOODWARD, B. B.
1931 – *The types of Lamarck's genera of shells as selected by J. G. Children in 1823.* Smithsonian Inst., Misc. Coll., vol. 82, no. 17, pp. 1-40.

news reports

AUSTRIA

RUDOLF GRILL

On January 14, 1956, the new library building of the Geological Survey of Austria was opened by the Minister of Education, simultaneously with the recently completed palynological laboratory. In his address, the Director outlined the importance of micropaleontological work in promoting progress in many phases of geological activity, with special reference to Austria. Due credit was also given to the Austrian pioneers in micropaleontology, who were unaware of the future importance of micropaleontology but, with their painstaking and, at the time, apparently unpromising work, laid the foundation of the indispensable methods of today. After the celebration, numerous guests visited the palynological laboratory. Dr. W. Klaus explained the techniques and scope of his work, which for the time being is concentrated on pre-Quaternary problems.

Professor Dr. M. F. Glaessner, of the University of Adelaide, recently spent several months in Austria. He attended the field meeting of the Austrian geologists in the Carnic Alps. He gave two lectures in Vienna, one at the Geological Survey, on the present state of petroleum exploration activities in Australia, and the other at the Geological Society, on aspects of regional geology in Australia. Toward the end of his highly successful and widely appreciated visit, he was awarded the degree of Correspondent of the Geological Survey, in recognition of his contributions to the geology of Australia.

R. Oberhauser has joined the micropaleontological staff of the Geological Survey. Because of his long association as micropaleontologist with the M.T.A. in Ankara, he is a specialist in Mesozoic foraminifera. In the lower part of the Upper Triassic, he reports, in addition to Lagenidae and agglutinate forms, various forms of *Trocholina* that may be identical with those described by Henson in 1947 from the Triassic of Iraq.

Since his return from Stanford University, Klaus Küpper has been working on the "Gosau" standard section, on which R. Noth had begun to work just before his untimely death. The present study of this area, which is a classic section of the eastern Alps, was concluded toward the end of 1955, and will soon be published.

A. Papp was recently honored with the title of "a.o. Professor." He has recently published some important contributions to micropaleontology and stratigraphy. The first concerns the biostratigraphy of the Upper Cretaceous of Carinthia (1955, Österr. Akad. Wiss., Math.-Naturw. Kl., Sitzber., vol. 164, p. 317-334). Papp proposes to designate the orbitoid-bearing beds of the Campanian as "älteres Orbitoiden-Senon," and those of the Maestrichtian as "jüngeres Orbitoiden-Senon." Another paper by Papp is on the orbitoid-bearing Maestrichtian of the Fruska Mountains of Yugoslavia, north of Belgrade (1954, Ann. Géol. Peninsule Balkanique, vol. 22, pp. 81-92, 2 pls.). This correlation still awaits a final check with cephalopod-bearing localities. Papp has also published a third paper, on Miogypsinidae from Oligocene beds just above the "Sotzkaschichten" of Yugoslavia (1955, Geologija, Ljubljana, vol. 2, pp. 168-178, 3 pls.). Here a rich fauna of smaller foraminifera contains *Miogypsina (Miogypsinoides)* cf. *formosensis* Yabe and Hanzawa.

O. Kühn has published a paper on Bryozoa from the Burdigalian, including a new genus and species (1955, Österr. Akad. Wiss., Math.-Naturw. Kl., Sitzber., vol. 164, pp. 231-248, 2 pls.).

S. Muldini has reported the micropaleontological results of an examination of a well in the younger Tertiary of Tuzla, Yugoslavia (1955, Austria, Geol. Bundesanst., Verh., no. 2). It is remarkable that here, at a distance of about 450 km., it was possible to establish the same microstratigraphic sequence as in the well-known Tertiary of the Vienna Basin.

R. Grill (1955, Austria, Geol. Bundesanst., Verh., no. 2) indicates that the famous "Badener Tegel" belongs to the lower Tortonian. These clays, well known by their macro-association of *Pleurotoma,* etc., seem to have been laid down under near-shore conditions, in bays well protected from currents or wave action.

K. Küpper has reported finding the skeletal elements of Ophiuroidea in the Austrian Tertiary for the first time (1954, Pal. Zeitschr., vol. 28, pp. 159-166, 2 pls.).

E. Kamptner has published an extensive treatise on fossil Coccolithinaeae (1955, K. Nederl. Akad. Wetensch., Afd. Natuurk., Verh., ser. 2, vol. 50,

no. 2, pp. 1-86, 9 pls.). The material forms part of the collections from Rotti gathered during the Timor Expedition (Molengraaf 1910/12), and examined in part for Radiolaria by Tan Sin Hok. One hundred new forms are described, which must be considered isolated elements of tests, their intercorrelation being unknown so far.

RUDOLF GRILL
Geologische Bundesanstalt
Vienna, Austria

FRANCE

JEAN CUVILLIER

Institut Francais du Pétrole

During 1955, the activities of the laboratory of micropaleontology were focused mainly upon contract work for oil or mining reseach organizations, such as explorations of the Bureau de Recherches de Pétrole in French West Africa (Senegal and Ivory Coast), explorations of the Bureau d'Etudes Géologiques in Central Africa (Sahara and Tanezrouft), on the island of Sao Tomé, and in France (Valence basin), work for mining research companies in Togo and Dahomey, French West Africa, and work for the Belgian Congo, on Mesozoic ostracodes.

In addition to these activities, some research was carried on and some papers were published by members of the laboratory staff. The scope of the research was, however, very limited. It is hoped that during the current year it will be possible to devote more time to studies that have already been started, such as the foraminifera of the Cretaceous-Tertiary passage beds and of the Paleozoic, and the Ostracoda of the Jurassic-Cretaceous passage beds and of the Lower Cretaceous.

University of Paris
Centre d'Études de Micropaléontologie

Various materials from France, Italy, North Africa, Cameroon and other localities, both in the collections and sent to the Centre for examination, were studied. Mme. M. Neumann continued work on her revision of the orbitoids of the Upper Cretaceous and Eocene of Aquitaine, which will probably be completed in 1956. D. Boulanger continued his stratigraphic and micropaleontologic study of the Nummulitic of Landes, where he has made some interesting new discoveries. Mlle. L. Biot, who is working on the phosphatic chalks of northern France, devoted part of her time to the identification of foraminifera collected by members of the laboratory staff. Mlle. F. Piketty, who had begun a study of the microfaunas of the Lower Eocene of Basses-Pyrénées, has left the Centre and is now working in Guadeloupe.

The teaching of micropaleontology was considerably expanded in November, 1955. It is under the direction of Professor Jean Cuvillier, who is assisted by Mme. Neumann and Boulanger. The University will henceforth grant a diploma in "Etudes Supérieures" to those who complete the course in micropaleontology.

Professor Cuvillier has sent the English edition of his "Corrélations stratigraphiques par microfaciès en Aquitaine occidentale" to the printers. This work, which includes about one hundred plates, carries additions and corrections to the French edition, which was published in 1951. The English edition is expected to appear in 1956.

University of Dijon
Laboratory of Geology and Micropaleontology

Under the direction of Professor R. Ciry, the laboratory is continuing its program of development, and instruction in applied micropaleontology was begun in 1955. A number of students were trained for careers as industrial micropaleontologists. Three important research projects are also under way or nearly completed. One is a study of the foraminifera of the Middle and Upper Jurassic (Bajocian to Rauracian) of Burgundy, both systematics and faunal associations, being carried on by H. Tintant. Another, by P. Rat, concerns the Cretaceous stratigraphy and microfacies of northern Spain. The third is a study of the smaller foraminifera of the Nummulitic of the Pyrenees, together with a biometric revision of the operculines, by J.-Ph. Mangin.

In addition, Professor Ciry has in progress a study of the genera *Meandropsina* and *Orbitolinopsis*. Mme. Mangin has completed the first part of a paper on the ecology of the smaller foraminifera of the Nummulitic of Aquitaine. Several studies of a more limited scope are also going on: S. Jardine is working on a foraminiferal fauna from the Maestrichtian of Navarre; F. Doillon is studying some samples from the Pliocene of Rimini, and Mlle. Baillou some from the Pliocene of Rhodes; while P. Cotillon and A. Menot are working on the Jurassic of Burgundy.

Société Nationale des Pétroles d'Aquitaine

Until April, 1956, A. Debourle and M. Delmas were at the Pau laboratory. After that time, Delmas went to take over the direction of the laboratory at Maxeville. He was replaced at Pau by R. Deloffre. The Pau laboratory has continued the study and revision of field and well samples, and has succeeded in completing and refining the data on the Upper Jurassic, the top of the Jurassic, and the Neocomian. Studies were also undertaken on the Cenomanian of the center of the Aquitaine basin, as well as a detailed study of Nummilites, principally by Deloffre. The Tertiary penetrated by wells in the Department of Landes has for more than a year posed numerous problems, which are still being studied. Field work has been directed toward studies of the Upper Cretaceous flysch, the terminal sandstone of

the Albian, and the Jurassic-Cretaceous passage beds. Debourle has reviewed the important problem of the Triassic of the Aquitaine Basin. He is also continuing the study of the microfaunas of the uppermost Cretaceous and Lower Eocene.

The Maxeville laboratory is under the direction of M. Delmas, who is assisted by M. Cabrit. They are undertaking a study of the microfaunas of the Lias of Lorraine, in an attempt to work out the distribution of the species. They are also beginning a revision of the stratigraphy of the Dogger and Malm of the eastern part of the Paris Basin. This revision will necessitate sampling the marly horizons of the Dogger and Malm in order to study the microfauna and work out the distribution of the species, as well as sampling the indurated horizons in order to identify characteristic microfacies and their associated microfaunal zones. The results obtained so far during 1955, on the basis of studies that are still continuing in 1956, can be summarized as follows: In the Dogger, some species with rather restricted ranges have been found among the genera *Textularia, Flabellammina, Lenticulina, Astacolus, Falsopalmula, Citharinella, Citharina, Epistomina, Discorbis,* and *Eggerella.* The genus *Kilianina* has been found at numerous Dogger localities, associated with various microfacies, at the top of the Bathonian. There are strong indications that the upper Bathonian is present not only at the center of the Paris Basin, east of Paris, but also to the south, in the Neufchâteau-Chaumont region. It is present there in facies very similar to a horizon called the "limestone with *Rhynchonella decorata,*" which was classified as upper Bajocian by P. L. Maubeuge, but it contains the genus *Kilianina.* The microfaunas and microfacies of the Malm have scarcely been touched upon, but it is expected that this study will be intensified, particularly with respect to the horizons with *Pseudocyclammina.* It is noteworthy that a horizon with *Conicospirillina basiliensis* Mohler has been discovered in the Lusitanian.

Société Esso de Recherches et d'Exploitations Pétrolières, Bordeaux

The micropaleontological laboratory was established in September, 1954. The staff is headed by F. Dalbiez, who is assisted by G. Malmoustier. The first task of the new laboratory was to interfile the Ellis and Messina Catalogue of Foraminifera. When that had been done, work began with the lithologic and paleontologic zonation of the Parentis oil-field sequence. On the basis of planktonic foraminifera of Tertiary and Cretaceous age, good correlations were obtained between the eighteen wells drilled in that area. Detailed studies of the dolomite-limestone reservoir, which belongs to the lowermost Cretaceous and locally to the top of the Jurassic, are carried on continuously in this area. Particular attention is paid to the Orbitolinidae, Spirillinidae, Eggerellinae, Lituolidae, and calcareous algae present in these beds.

Other studies were concerned with ten other wells, which penetrate a geologic column ranging from Paleozoic to Recent. The Jurassic beds were studied in particular, and a stratigraphic sequence was established.

The microphotographic and stratigraphic files are continually being improved. Besides foraminifera, which are used in current work, Jurassic ostracodes have been studied by Mlle. Regnier. Several investigators have also studied the possible applications of pollen, spores and organisms incertae sedis in stratigraphy. Dalbiez is continuing his studies on Globorotaliidae and his revision of Cretaceous type sections.

Visitors to the laboratory were numerous during 1955. Dr. Stainforth of the Carter Oil Company spent three months at the beginning of 1955 helping to start the work. Other foreign visitors were Professor Reichel, with some of his students, and Dr. Z. Reiss. All future visitors will also be welcome.

Compagnie d'Exploration Pétrolière, Chambourcy

Under the direction of Mlle. G. Aurouze, the laboratory has been working principally on Jurassic and Cretaceous samples from wells drilled in the Paris Basin. On the basis of the foraminifera and ostracodes found in the samples, together with field samples collected previously, it was possible to establish a stratigraphic sequence. Previously, a study had been made of the Jurassic and Cretaceous sequences in Languedoc.

Régie Autonome des Pétroles, Saint-Gaudens

Routine work on well and surface samples was carried on in the main laboratory at Saint-Gaudens, under the direction of V. Pérébaskine. The microfaunas studied, in washed residues as well as in thin section, came primarily from the Paleozoic and Mesozoic formations of various regions in France and in the Sahara (CREPS). Microfacies and heavy minerals were also studied in detail.

JEAN CUVILLIER
Centre d'Études de Micropaléontologie
Paris, France

GREAT BRITAIN

TOM BARNARD

University of London
Imperial College

Inasmuch as D. J. Carter is doing work for oil companies in Pakistan, his study of the foraminifera from the Coralline Crag of East Anglia has been delayed. Nyi Nyi has now completed his thesis on Holocene foraminifera from northwestern England. Gwyn Thomas is at present working on charophyte gyrogonites from the upper Old Red Sandstone of southern Wales.

University of London
King's College

C. G. Adams has completed his work on upper Lias foraminifera from northern Lincolnshire, and it is hoped that his paper on this work will be published shortly. At present he is working on the palaeoecology of the fauna of the Lincolnshire limestone (Middle Jurassic), including a study of the microfossils.

University of London
University College

S. McNicol is continuing his study of the foraminifera of the Bathonian (Middle Jurassic) rocks of southern England, and has already made some interesting discoveries. W. Gordon has almost completed his work on the foraminifera of the Corallian (Middle Jurassic) of England. A. J. Martin, who is working on the sedimentology of the Middle Jurassic rocks of the Central Cotswolds, is also studying the microfaunal facies. M. W. Hughes Clarke is back at work again after an unfortunate attack of poliomyelitis; we all wish him a speedy and complete recovery. At present he is continuing his interesting studies of Albian Ostracoda.

D. A. Rasheed is preparing a thesis on some Recent foraminifera from the coasts of New Guinea. J. E. Robinson is preparing his thesis for publication while enlarging the scope of his work on Carboniferous ostracodes and other microfossils. A. J. Lloyd has nearly completed his study of the foraminifera of the type Kimmeridgian of Dorset. He hopes to extend this work and to correlate this area with that of the coast of northern France. Tom Barnard is publishing his work on the foraminifera of the Lias of England, and is continuing to study the foraminifera of the Upper Cretaceous of Britain. He also hopes to publish the results of his work on the Lagenidae in the near future.

University College of Wales, Aberystwyth

Professor Alan Wood is continuing his research on the wall structure of the foraminifera, and has extended the study to include Australian and Russian forms collected during the past year. Mr. Walters is studying the foraminifera of the Gault (Albian) of England, including material from a deep boring in the Thames Estuary. Mr. Harris is continuing his work on Recent foraminifera from the seas to the north of Scotland and the northern part of the North Sea. Mr. Jenkins has started work on some Tertiary foraminifera from Australia and will be visiting Australia during the next session.

University of Birmingham

Professor F. W. Shotton states that work has continued on microfossils, mainly conodonts and fish fragments, at various horizons including and below the Ludlow Bone Bed (Upper Silurian). Studies of peat profiles dating back to late glacial deposits are in progress.

University of Cambridge
Sedgwick Museum

N. F. Hughes, R. A. Couper and F. R. Gnauck are working on dispersed plant-microfossils of the British Mesozoic and Paleogene. These include megaspores and leaf cuticles, pollen and microspores. Attempts are being made to establish both their botanical affinities and their stratigraphic value.

University of Cambridge
Subdepartment of Quaternary Research

H. Godwin, the Director of the Department, has continued his work on the Somerset levels. D. Walker has again resumed his research based on detailed pollen analyses from selected areas in the Eden Valley and the Lake District. Work has continued on the geologic, climatic and vegetational conditions of the late glacial period. J. J. Donner in Scotland, D. Walker in the Lake District and Vale of Eden, and B. Seddon in northern Wales have pursued more or less parallel investigations into conditions of this period. B. Seddon has completed a long pollen series from Llyn Dwythwch, near Snowdon. This gives a comprehensive picture of the vegetation of the neighbourhood through the glacial period. R. G. West is continuing his research on East Anglia.

University of Hull

J. Neale is at present working on ostracodes from the Speeton clay, combining this work with a more general palaeoecological study of the Lower Cretaceous.

University of Edinburgh

W. J. Clarke has completed his thesis on Scottish Carboniferous conodonts, and is now preparing it for publication.

British Petroleum Company, London

F. E. Eames and W. J. Clarke are working on Tertiary and Cretaceous faunas from Kenya, Tanganyika and Sicily. E. Schijfsma has been working on Neogene faunas from Sicily.

British Museum (Natural History)

R. H. Hedley has been appointed head of the Foraminiferal Section. He wishes to draw the attention of authors to the fact that, in future, all reprints for the library of the foraminiferal department should be addressed to him. He would like to emphasize the importance of the library in the efficient working of his department.

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JAPAN

KIYOSHI ASANO

On the occasion of the Sixty-third Annual Meeting of the Geological

Society of Japan, held in Kyoto City from the 2nd to the 4th of April, 1956, nearly 400 geologists and paleontologists attended, and 283 individual lectures were presented. Some of the sessions were concerned with subjects that are important in relation to micropaleontology. These included three symposia and ten lectures on foraminifera. A symposium on the Japanese Paleogene included a discussion of newly discovered Paleogene foraminifera from Kyushu, based upon a biostratigraphic study by K. Asano and S. Murata. The problem of the correlation of Kyushu with the Paleogene stratigraphy and microfauna of Hokkaido was also discussed. Another symposium, on the Japanese Mesozoic, included a report by K. Asano, Y. Takayanaki, and T. Kotaka, on newly discovered Cretaceous smaller foraminifera of Hokkaido and their future application in the subdivision of the Cretaceous rocks. There was also a symposium on the Japanese Permian, based on the interrelationships of the fusulinid zones previously recognized in the Permian rocks. The discussions were by H. Fujimoto, R. Toriyama, R. Morikawa, K. Nakazawa, K. Ishii, K. Kanmera, K. Tachibana, M. Minato and Y. Onuki.

The ten individual lectures included papers on Recent, Pleistocene and Neogene foraminifera and on the results of pollen-analyses of coal-bearing beds. In Japan, emphasis has recently been placed on the importance of sedimentary facies in biostratigraphy.

Tohoku University

Professor S. Hanzawa has completed a monographic study of the foraminifera of the South Seas Islands formerly under Japanese mandate, and is now carrying on research on the fusulinid faunas of the Permian and Carboniferous rocks of Japan. He is also working on the microfacies of the foraminiferous rocks of Japan, and has already made numerous photographs.

In Volume 27 of the Science Reports of Tohoku University, Professor K. Asano published two parts of his study on Recent foraminifera dredged by the S.S. Soyo-Maru from the continental shelf surrounding Japan. This work was begun twenty years ago. Among the specimens studied, there were many *Nodosaria* measuring 50 mm. in length.

Y. Takayanagi is now working on Cretaceous foraminifera from Hokkaido, with a view to making a biostratigraphic analysis of the fauna, which includes numerous *Globotruncana* and *Gümbelina*. Also, in collaboration with K. Asano, he is undertaking a biostratigraphic study of the Neogene rocks of the Boso Peninsula, Chiba Prefecture.

Professor K. Hatai has just published a short article on Recent fish otoliths. He believes that partially land-locked waters influence the development of local races. He also has a paper in press on fossil otoliths from the Pliocene rocks of the Boso Peninsula.

Kyoto University

Dr. M. Morishima has been working on marine sediments from the Setouchi Sea, with regard to the ecology of the foraminifera. His results, when published, are expected to be valuable to those working on fossil assemblages.

Osaka University

K. Nakaseko is studying a radiolarian fauna from the Japan Sea.

Kyushu University

T. Sudo is studying Tertiary foraminifera from Miyazaki Prefecture, as well as Recent foraminifera from the Ariake Sea of Kyushu. The comparative work on fossil and Recent foraminifera which he is now carrying on may throw more light on the relationships between the faunas of these two ages.

Kyushu University of Technology

S. Murata has been making a survey of the foraminiferal faunas of the Paleogene rocks of Kyushu. A result of this study, carried on in collaboration with K. Asano, is the recognition of eight foraminiferal zones.

Kagoshima University

Professor N. Hatae has recently discovered *Nummulites* on the island of Amakusa, Kyushu. It is therefore believed that the stratigraphy of the island is probably in need of revision.

Tokyo University of Education

Y. Fujita has published the results of a study of variation in Japanese specimens of *Elphidium crispum*. He has examined specimens from a number of Recent and fossil localities distributed over a wide area.

H. Ujiié has published a paper on the internal structures of some Elphidiidae, and another on a new Recent genus, *Pseudocibicidoides*. He expects to make further studies of internal structures, in order to interpret intergeneric and interfamily relationships.

H. Igo has published a paper on Lower Permian fusulinids derived from pebbles of the Osobudani conglomerate. He described a new type of shell wall.

Natural Resources Institute

Y. Kuwano now has in progress studies on the foraminifera and ecology of marine sediments from Tokyo Bay.

Petro'eum Resources Exploitation Company, Ltd.

Recently the Mining Section of the Teikoku Oil Company became an independent company, and was named as indicated above. Both macro- and micropaleontology have become very important in the work of the company. During 1955 and 1956, sampling and stratigraphic work have been carried on in the Kwanto District and in Hokkaido.

KIYOSHI ASANO
Institute of Geology and Paleontology
Tohoku University, Sendai, Japan

SPAIN

GUILLERMO COLOM

A laboratory of palynology was founded last year at the Museo de Ciencias Naturales of Madrid. It is under the direction of Dr. Josefina Menendez Amor, and is now actively engaged in pollen-analysis. An interesting collection of fossil fruits and seeds, chiefly Upper Tertiary, is being assembled. Another collection, consisting of modern fruits and pollen grains for comparison, when necessary, with fossil specimens obtained from peat bogs and clays, is nearing completion. Some five hundred fruits have been mounted.

Last summer, Srta. Menendez Amor, together with Professor Florschutz of the University of Leiden, Netherlands, made field trips in various Spanish provinces to collect material for the determination of the age of their peat and clay deposits. An account of their conclusions on the floral history of the Iberian plateau during the Quaternary will probably be presented at the International Congress of the INQUA, to be held at Madrid in June, 1957.

An extensive paper on Carboniferous megaspores of Spain, by Dr. S. J. Dijkstra of the Geological Bureau of the Netherlands, Haarlem, was published in "Estudios Geologicos," Madrid (nos. 27-28, December, 1955). The author explains the stratigraphic significance of megaspores and the methods employed by him for their extraction from Spanish coals; he describes the external characters of the spore wall, and remarks on nomenclature and classification. Descriptions are given of the species found in material from the coal basins of Puertollana, Ciudad Real; Peñarroya-Belmez, Cordova; Villanueva del Rio, Seville; Valdeinferno, Cordova; San Cebrian de Muda, Palencia; and various localities of the central basin of Asturias. These descriptions are followed by the author's conclusions on the age of these basins. This paper carries a list of descriptive terms relating to megaspores in Latin, Spanish, French, English and German. There is also an extensive abstract in English, including detailed systematic descriptions of the spores.

Dr. Conchita Bonet, an assiduous worker on the Carboniferous spores of Asturias, was present at the international meeting of the Commission on Nomenclature of Carbon Petrology held at Liége in May, 1955. On this occasion, Dr. Bonet also studied new methods of spore extraction from coals of low volatile content, under the direction of Dr. R. Noel.

As her doctor's thesis at the University of Madrid, Srta. Trinidad del Pan has presented a memoir on the Vindobonian foraminifera of the lower Guadalquivir basin. This is the most complete and extensive study ever made of the smaller foraminifera of the region of Seville, and we look forward with interest to its publication.

Dr. N. Grékoff, of the Institut Francais du Pétrole, has been studying the Ostracoda of the formations of Wealden age in the northeastern part of the Iberian Peninsula. In a paper that will appear shortly in "Estudios Geológicos," he describes a number of species and indicates their stratigraphic correlations with other areas of western Europe. In the complex stratigraphy of the Spanish Wealden, this interesting study will give us our first data on the ages and biofacies of these deposits, which are always of considerable thickness in this part of Spain.

Your correspondent is working on the lithology and micropaleontology of the Sierras Beticas. A preliminary study of Mesozoic sedimentation in the Sierra de Ricote, Province of Murcia, has revealed the presence of very pure radiolarites in that region. Recently, thanks to Professor Fontboté and the French geologist Abbé de Lapparent, who have made extensive field trips in southern Andalusia, I have been the receipient of a considerable amount of Mesozoic and lower Tertiary material. On the basis of this material, I hope to arrive at a more precise knowledge of the sedimentary sequence deposited throughout the Betic geosyncline.

GUILLERMO COLOM
Soller, Mallorca

UNITED STATES — EAST-CENTRAL

R. V. KESLING

University of Illinois

Frank H. T. Rhodes has many active research projects. He is working on Cambrian microfaunas from New Zealand, Devonian conodont faunas from southwestern England, Pennsylvanian conodont faunas, Devonian agglutinated foraminifera (with N. Haack), and hystrichosphaerids (with E. Borden). He has recently published two fine articles on conodonts: "The conodont fauna of the Keisley limestone" (Geol. Soc. London, Quart. Jour., vol. 111, pp. 117-142, pls. 7-10), and "The zoological affinities of the conodonts" (Biol. Rev., vol. 29, pp. 419-452). With Eugene S. Richardson and Ranier Zangerl of the Chicago Natural History Museum, Dr. Rhodes is continuing on the paleoecology project reported in this jour-

nal in January. He also found time recently to make some taxonomic studies on the genus *Prioniodus*, with Dr. Klaus Mueller of the University of Iowa.

Harold N. Scott is doing some ostracode work for the Treatise on Invertebrate Paleontology. He reports that Allen Braumiller may work on the Zygobolbidae.

Illinois State Geological Survey

Robert M. Kosanke recently published two papers: "Correlation of coals and spore analysis" (Missouri School of Mines, Bull., Tech. Ser., no. 85), and "*Mazostachys*—A new calamite fructification" (Illinois, Geol. Survey, Rept. Invest., no. 180). At present he is working on the delineation of additional spore populations of Mississippian and Pennsylvanian deposits. He also reports the following news from the Survey:

Mrs. Marcia R. Winslow is conducting a project on megaspores of Chesterian and Pennsylvanian age. Her paper "Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio" is being reviewed and edited as a Professional Paper of the U. S. Geological Survey.

Fred Cropp, who will receive his master's degree at the University of Illinois in June, is completing a thesis on delineation of spores from the Black Warrior Basin.

Dave Reinertsen is chiefly interested in spores of Pennsylvanian age. His master's thesis concerned spores of the Summit coal bed from Boone County, Missouri. He has also given consideration to a number of other Pennsylvanian coal beds from Missouri.

University of Chicago

At the Enrico Fermi Institute for Nuclear Studies, Cesare Emiliani has research projects under way concerning paleotemperatures of North Atlantic deep-sea cores, and mollusks from Mediterranean caves and Pleistocene beaches. During 1955, he published papers on oxygen isotopes and paleotemperature determinations (Actes IV. Congr. INQUA, Rome, 1953), on Pleistocene temperatures (Jour. Geol., vol. 63, p. 538) and on the mineralogical and chemical composition of the tests of certain pelagic foraminifera (Micropaleontology, vol. 1, no. 4).

Indiana University

J. J. Galloway and J. St. Jean, Jr., are actively studying Devonian Stromatoporoidea from Indiana, Kentucky, and Ohio. They recently published "A bibliography of the order Stromatoporoidea" (Jour. Pal., vol. 30, pp. 170-185). St. Jean has moved to Trinity College, Hartford, Connecticut.

T. G. Perry is currently doing research on non-fenestrate bryozoans from the middle Chesterian rocks of Indiana and northern Kentucky. He and H. H. Gray, of the Indiana Geological Survey, have a paper scheduled for publication this summer, entitled "Local lithologic discontinuities in the Reelsville (lower Chester) limestone of Indiana" (Amer. Assoc. Petr. Geol., Bull., in press). Perry recently published two abstracts on Bryozoa: "Restudy of the genus *Fistulipora* through Hall's types" (Geol. Soc. Amer., Bull., vol. 64, p. 1463), and (with Donald E. Hattin) "Osgood (Niagaran) bryozoans from the type area" (Ibid., vol. 66, pp. 1695-1696).

Indiana Geological Survey

G. K. Guennel has published "An interesting megaspore species found in Indiana block coal" (Butler Univ., Bot. Studies, vol. 11). He is now studying the correlation of Pottsville coals in Indiana by means of plant spores. He is also interested in Pleistocene pollen.

Notre Dame University

Since the last report, R. C. Gutschick has published "Sponge spicules from the Lower Mississippian of Indiana and Kentucky" (Amer. Midland Nat., vol. 52, pp. 501-509). He is now investigating arenaceous foraminifera from the Middle Ordovician Platteville formation of northern Illinois, and the general micropaleontology of the Redwall limestone of northern Arizona.

University of Michigan

Jane Inch Smith, now teaching at Michigan State University, is working on Middle Devonian ostracodes from Charlevoix and Emmet Counties, Michigan, for her doctor's problem. George Soronen is writing a master's thesis on the ontogeny of the ostracode species *Welleria aftonensis* Warthin.

Your reporter confesses, with proper embarrassment, that he has research under way on megafossils — crabs from the Pacific and crinoids from Michigan. Several other projects, quite legitimately micropaleontologic, are also being followed up, including some new ostracodes from the Middle Devonian Rockport Quarry formation, a technique for investigating internal structures of carapaces, and (with G. M. Ehlers) Devonian ostracodes from Big St. Martin's Island, Michigan. He is also still working on parts of the ostracode volume for the Treatise on Invertebrate Paleontology. Recent publications include: (with M. J. Copeland) "A new occurrence of *Semitextularia thomasi* Miller and Carmer, 1933" (Michigan, Univ., Mus. Pal., Contr., vol. 12, pp. 105-112), "A new occurrence of *Oncotechmonus chemotus* Kesling, a Middle Devonian entomoconchid ostracod" (Ibid., pp. 175-178), "Notes on two Ordovician ostracods from Estonia" (Ibid., pp. 259-272), "Two new species of ostracods from the Centerfield limestone of western New York" (Ibid., pp. 273-284), (with Philip L. Wagner) "Silurian ostracods collected by Dr. Carl Ludwig Rominger from glacial deposits in Germany" (Ibid., vol. 13, pp. 33-78), and "The ostracod — A neglected little crustacean" (Turtox News, vol. 34, pp. 82-86). In press are: "Notes on Zenker's organs in the ostracod *Candona*" and a short article on an Upper Cretaceous crab.

Wayne University

John T. Sanford has a research project on Ordovician foraminifera.

Ohio State University

Mildred F. Marple is continuing her work on Pennsylvanian ostracodes in Ohio. Walter C. Sweet is studying Cincinnatian conodont faunas (particularly those of the Eden), the morphology of neurodontiform conodonts, and Middle Devonian scolecodonts from the Columbus limestone in Ohio. He and Grace Ann Stewart have published "Conodonts from the Middle Devonian bone beds of central and west-central Ohio" (Jour. Pal., vol. 30, no. 2, pp. 261-273).

Miss Stewart writes that she is now busily engaged in micropaleontological studies with the Canadian Stratigraphic Service, 705 Eleventh Avenue West, Calgary, Alberta, mostly of a confidential nature for oil companies. She says the fossils are beautiful, and that she has seen none better.

Charles Summerson reports that he is finishing up the work on Devonian arenaceous foraminifera, and will turn his attention to Pennsylvanian holothurians and ostracodes.

United States Geological Survey
Coal Geology Laboratory, Columbus, Ohio

James M. Schopf sends in the following report:

In September, 1955, Mrs. Marcia Winslow, now with the Illinois Geological Survey, completed a manuscript report on plant spores and other microfossils from Upper Devonian and Lower Mississippian beds in Ohio. About eighty separate taxa, including identifiable wood fragments, disseminules of *Tasmanites*, and hystrichosphaerid cysts, in addition to spores, are described and their stratigraphic distributions recorded. The report is now in process of review.

C. J. Felix and J. M. Schopf have resumed the study of spores from the Breathitt formation in Kentucky, primarily for the purpose of identification of certain coal beds. A distinctive microfossil assemblage, including water fern (aff. *Azolla*) and *Isoetes* megaspores, has been discovered in Paleocene coal beds of Harding County, South Dakota, by J. M. Schopf, R. J. Gray, and C. J. Felix.

Miami University

William Shideler is now working on the entire microfauna of the Cincinnatian, especially that of the Richmond, in Ohio, Indiana, Kentucky, Tennessee, Illinois, Michigan, and Wyoming.

University of Cincinnati

John H. Hoskins, of the Department of Botany, is studying fructifications (spores) in Paleozoic coal balls. In collaboration with Maxine Abbott, he recently published a paper entitled "*Selaginellites crassicinctus*, a new species from the Desmoinesian of Kansas" (1956, Amer. Jour. Bot., vol. 43, no. 1, pp. 36-46).

Other news

H. N. Coryell, 249 Claranna Avenue, Dayton, Ohio, is working on the micropaleontology of the "Trenton" in well cuttings from near Sydney, Ohio. His "Bibliography of Mesozoic Ostracoda, classification and revisions" will be published by the Geological Society of America, and is now in press.

Howard R. Schwalb, of the Phillips Petroleum Company, Evansville, Indiana, recently had his "North American Paleozoic Chitinozoa" published, as Illinois Geological Survey Report of Investigations no. 186. He has now turned his attention to foraminifera, and presented a paper on specific variations in Silurian foraminifera at the April meeting of the American Association of Petroleum Geologists.

The following persons indicate that they still have an active interest in micropaleontology, although their work is not now directly connected with it: J. W. Huddle, U. S. Geological Survey, Euclid Avenue Classroom Building, University of Kentucky, Lexington, Kentucky (conodonts and foraminifera); E. Nosow, Box 282, Hopkinsville, Kentucky (Bryozoa); and Norman L. Thomas, Pure Oil Company, 35 East Wacker Drive, Chicago, Illinois (general and ecology).

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